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THE TEACHING OF SCIENCE AND THE SCIENCE TEACHER

THE RELATIONSHIP OF SCIENCE TEACHING TO EDUCATION IN GENERAL, WITH ESPECIAL REFERENCE TO SECONDARY SCHOOLS AND THE UPPER ELEMENTARY GRADES

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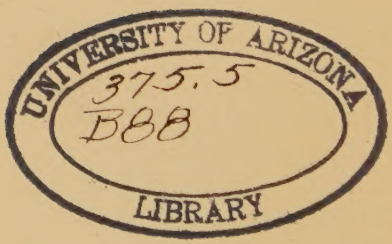

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PREFACE

This text on the teaching of science is intended for use in teacher-training institutions, and by science teachers already in service who feel the need of suggestions for the betterment of their work. The book is an outgrowth of the experiences of the authors—one as head of a science department (Chemistry) in a large city school system, and the other for many years engaged in fitting students to teach high school sciences.

Throughout the book the "human element" has purposely been kept prominent. The teacher, and the pupils being taught, constitute the dominant factors in all discussions. It is conceived by the authors that in a very real sense the success of any science teacher even as of other teachers can properly be gauged by what his pupils learn. His instructional efforts primarily are not to make scientists of his pupils, but rather men and women intellectually responsive in ways that are characteristically scientific.

It is primarily the desire of the authors to be of service to beginners in science teaching, and to all who are making a study of science teaching.

They believe that any selections and adaptations of subject matter, and all methods of presentation for teaching purposes, are distinctively means rather than ends in an educational process. Chief among these ends in the minds of science teachers should be that kind of thought stimulation and that kind of development of power to think constructively whose natural results are not only trained intellects but also an abiding "desire for the truth" in all matters.

In all discussions throughout the text a unity for all science teaching, in large and in small high schools alike, is found in the common aims of science teaching rather than in any likeness of equipment, of teacher qualifications, or of the numbers of pupils handled. A clear understanding of the purposes and principles of science teaching necessarily contributes to unity of effort among science teachers from nature study courses onward, and tends to supplant a diversity in teaching so notably in evidence in science instruction.

The authors desire to acknowledge especial obligation to Mrs. Louise Brownell Trow for her assistance in the preparation of a section dealing with the biological sciences for which her training especially fits her; and to Dr. F. E. Henzlik of Teachers College, University of Nebraska, and Dr. William Clark Trow of the College of Education, University of Cincinnati, for their reading of the manuscript.

Thanks are due likewise to those who as students have worked with the authors in classroom and laboratory to verify and clarify the beliefs and practices set forth in these pages.

HERBERT BROWNELL.
FRANK B. WADE.

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PART I

CHAPTER I

PLACE OF LABORATORY WORK IN THE TEACHING OF SCIENCE

Through wisely chosen laboratory exercises, and efficient laboratory administration, science teaching accomplishes its notable part in school instruction. Without its experimental aspects science teaching when attempted is largely shorn of its distinctive features and educational possibilities. How much there shall be of this experimental work in any science course, and what shall be the requirements for supplies and apparatus, are variables in the teaching scheme. *But whether or not the instruction is on a laboratory basis* constitutes a determining factor in evaluating "science courses." Through laboratory exercises there can be developed, stimulated and directed a desire to learn on the part of pupils. These exercises should beget a teachableness in pupils fundamental in the learning process, and should provide a way for rapid acquisition of knowledge. Discussions of the place and importance of laboratory work then naturally demand attention.

Laboratory work in all science teaching may very properly be considered as a first hand study of phenomena. This contrasts sharply with studies *of state-*

ments concerning phenomena as these are set forth in books. In high school science both these phases of the teaching process must be insisted upon as indispensable. Science studies without laboratory exercises are scarcely worthy of their name. And this is as true of introductory courses such as general science as it is of chemistry and other more advanced high school science branches. The character of exercises suitable for pupils in the various sciences must of necessity be varied both by reason of the immediate ends to be secured, and because of differences in the maturity and preparation of pupils. The classroom instruction in all cases, however, should center around laboratory work. This laboratory work should never become in the estimation of classes merely an adjunct to classroom instruction. Naturally this view of it is held by pupils when it is scheduled for certain days only in rooms dedicated solely to this kind of work, and when perchance its topics are unrelated to those under discussion at the time in the classroom.

Laboratory exercises are not only a means for first hand information concerning facts which are fundamental in the discussion of topics, but in addition they should be thought-provoking. The facts in themselves are not enough. There must be apparent to pupils certain relationships between these facts as they note the results of the experiments being performed. There must be such a continuity in these relationships as shall constitute a well-defined thought process, natural

and progressive even when elementary. Wisely-chosen and well-managed laboratory exercises furnish these possibilities in thought processes. This involves not only numbers of facts called to the attention of pupils, but their usableness both in interpreting knowledge previously gained through experience, and in unifying what is known with newly acquired information. (See Part II—Nature Study, and Appendix D.)

Facts learned through wisely chosen laboratory exercises have with beginners in science a worth in mental processes not possible for information gained from the formal statements of text and reference books. These facts exceed in worth the teachings of experience to the extent that they are better comprehended and related, and they are more likely to be remembered. When enough of these laboratory exercises have been performed, pupils are mentally equipped for the more rapid interpretation and assimilation of facts as summed up in books wherein the experiences of others are set forth. The attention of pupils having been centered upon a topic, and their interest aroused by laboratory contact with certain of its phases, it may be confidently expected that to some degree at least there has been developed a desire for further knowledge concerning the topic. In the teaching process this becomes the time of all times to turn to text and reference books for further information which has been gained through the experience of others. Facts too numerous or too difficult of acquisition for the beginner

to attempt to collect for himself are thus supplied. Practical applications and natural relationships to previously acquired knowledge, together with any historical setting, may now come under consideration.

The question of just when and where in laboratory and classroom a transition shall occur from the realm of investigation to the study of what others have learned constitutes an ever recurring "teaching problem." Its correct solution involves experience, aptitude in teaching, and not least of all an understanding of conditions and motives for mental activity. To meet this need for an intimate definite knowledge of the mental states of individual pupils, no opportunities for learning excel those offered in the laboratory. There, free from restraints of the class period, the work is more largely individual teaching. It is rendered as individual need arises. In the laboratory the dominating power of one person over another, summed up in a teacher's "personality," yields its largest teaching values.

Experiments of whatever grade of difficulty are the best of means both in the laboratory and in the classroom of "arresting attention," "stimulating interest," and "arousing a desire to know." The phenomenal element in them, however simple it may be, is a challenge to any normal mind to "see what happens." No better means in the hands of teachers is available for arousing and for renewing interest in discussions than

is offered through experimental exercises simple in manipulation and easy to comprehend.

Each laboratory exercise may be characterized, too, as a problem the solution of which is made possible for the pupil, provided he makes use both of the appliances at hand and of what he knows. This is regardless of whether the knowledge he possesses was learned in or out of school. Something is required done by the pupil, and the doing must conform to certain conditions stated or implied. These conditions *must always be under control.* There must be a well-defined purpose, too, in what is done, *and to the pupil it must be something quite worthwhile.* The results attained *as facts,* and the conclusions based upon these facts, constitute a solution of the problem. In and through all these solutions full use should be made of what the pupil already knows as gained by experience. It is the vivifying element in the instruction given, and maintains the unity of life in and out of the schoolroom. (See "Teaching-Projects," p. 68.)

During the first weeks of a science subject it may be well in many high schools to have the instructor do much of the experimental work, possibly all of it. In this way pupils in a class have opportunity to get into the spirit of the new subject before being overwhelmed with requirements unfamiliar to them. Observation by the pupils of this experimental work done by the teacher, including the results obtained by him

and the interpretations placed upon these results through class discussions of them, creates a confidence on the part of pupils concerning what they themselves may be able to do and to learn through their own laboratory studies.

This in some measure seeks to regain and retain the wonderfully effective demonstration work of the old-time lectures in Natural Philosophy. It is to be kept in mind, however, that whatever adaptations are made in high school science courses, there must ever be retained a large measure of the instructional effort involved in using the question-and-answer method. While a greater rate of progress is commonly made where the experimental work is done by the teacher, there must needs be maintained throughout it all the fullest measure of individual pupil participation both of observation and of inference. Especially is this true at the outset of the course. Freedom of pupils from manipulation of strange apparatus should contribute to such participation. Where pupils in the science courses are set at laboratory work from the first in these beginning exercises, there should be no serious difficulties of manipulation. The exercises should deal with simple and fundamental subjects such as are likely to prove of interest to the pupil, and as a rule should require only familiar material and apparatus.

In small high schools there is less need to observe hard and fast divisions of time into class and lab-

oratory periods. In the larger high schools the size of classes, and the number of sections in a science subject, may necessitate these arrangements for administrative purposes. Quite an ideal condition exists when a double period daily is at the disposal of a science teacher. All preparation of lessons from experiments or from books, all discussions of text material and of lists of questions, and all solutions of problems and of quantitative experiments, may then be accomplished within this time. Changes may be made at any time from one kind of work to another as the nature of the work and progress of the class demands. All preparation then becomes supervised study, and no outside lesson preparation in the subject is required. Actual experience with these ideal conditions shows that the additional cost in time of teacher per pupil is in no small part compensated for by the much smaller per cent of failures of pupils. There is time under this system, too, for trips during school hours to nearby factories and shops, to industrial and municipal plants without interference with other school work. What is learned on these trips is likely to be remembered long after much of the textbook material is lost.

Changes may be made at a moment's notice at any time during these double periods from class thinking to individual efforts, from instruction of a personal type to general discussions. Elimination of much waste of time in preparing lessons, and the formation of right habits of study, become possibilities. The laboratory

becomes in truth a workshop where "scientific attitudes" and "scientific methods" are in evidence. It is to be said in this connection, however, that heavy demands are made upon teachers by any such arrangement. It requires a large expenditure of energy, and noteworthy executive and administrative ability. But the live and growing teacher exults in such opportunities.

In large or crowded schools even where the double period is enjoyed it may be necessary for classes to alternate between laboratory and classroom, being in the laboratory only every other day. In these cases much can be done to make the sequence of events a natural rather than an artificial one. By careful planning every minute of the laboratory time may be made available for experimental purposes. A few closely related experiments can be done in one day, and the class discussion of them and their "write-up" can come the following day in the classroom. The use of any reference books, all presentations of new topics, etc., can be reserved for the double period in the classroom. Thus the undoubted limitations due to an inability to have access to the laboratory or the lecture room at will are at least minimized.

Summary

1. Laboratory work as the correlating center of science studies.
2. Laboratory exercises as thought provocation. Elemental nature of thinking.

3. Teaching value of knowledge gained experimentally.
4. Transition involved from first-hand investigations through experiments to use of text.

   Opportunities of the laboratory to know capabilities of individual pupils.
5. Use of experiments to arrest attention, and to stimulate interest.
6. Laboratory exercises as "problems."
   (a) Nature of an experiment.
   (b) Relation of individual experiences to laboratory exercises.
7. Experimental work during the first weeks of a course. Advantages.
8. Double periods for science classes. Changes from one kind of work to another.
   (a) Character of work done as "supervised study." Advantages of scheme.
   (b) Ability demanded of teacher.

CHAPTER II

CHARACTER OF THE LABORATORY EXERCISES, AND THE LABORATORY MANUAL

What the nature of the exercises required in secondary school science shall be depends necessarily upon what purpose the laboratory work has in the teaching scheme. With different sciences taught and with varied teaching conditions in different schools, to say nothing of teachers and pupils and texts and manuals as variable factors, any unity of instruction in high school sciences must lie in their aim rather than in the details of any method. Fortunately there are certain general conditions applicable alike to laboratory work in all the sciences. Waste and inefficiency go hand in hand with laboratory work which on the part of an instructor lacks well-defined purposes and plans. Dependence upon the order of topics given in a text, and upon directions for laboratory exercises as given in a manual is not sufficient. A clear appreciation of the purposes of the laboratory, and of its exercises in any teaching scheme as a whole, must be had by the science teacher as preparation for his work.

For simplicity of discussion, laboratory exercises of all secondary school sciences may roughly be grouped

either as qualitative or quantitative in character. The nature of this classification is apparent in the names. Account cannot be taken here of the special difficulties incident on the one hand in handling the numerous laboratory sections of large city high schools, and on the other in meeting the varied and often unrelated demands made upon science teachers in the smaller high schools. Executive ability of no mean order is required for laboratory administration in high school science teaching. A necessary adaptation of the means at hand to the ends sought intensifies its diversity in procedure. In nowise, however, does this make impossible a unity in purpose such as set forth below. That science teachers may in large measure have failed to agree upon any major aims, and may have over-emphasized the importance of exercising the greatest of freedom in choice of purposes, is perhaps all the more reason for the presentation that follows.

The primary aim of secondary school science is conceived as having a three-fold aspect set forth as follows: To promote the development of a scientific attitude in pupils; to enable them to become skilled in the acquisition and organization of facts pertaining to any topic whether in school or out; and to become competent to reach general conclusions *legitimately based upon the facts under consideration.* The laboratory work upon any topic thus becomes a preliminary study of that topic. Pupils have brought before them through simple laboratory exercises certain facts con-

cerning a topic. To the fullest degree possible *these facts should be thought-provoking, and should possess an inherent interest for the pupil.* Some or all of the exercises may be worked out by the teacher, and class discussions and explanations may occupy portions of the time set apart as a laboratory period. But it is the pupil who must acquire and relate these facts up to the full limit of his ability to do so. Waste of time, and the discouragement which results from attempts by a pupil to accomplish what is not clearly understood either in nature or in process, is at no time permitted to continue under efficient laboratory administration.

Sufficient comment made by an instructor upon the purpose of any set of laboratory exercises at the time of its assignment should make clear to pupils an understanding of it as a worth while undertaking. Brief mention should be made concerning any special precautions to be taken, and any serious difficulties to be met. This goes far towards an elimination of misunderstandings and of aimless effort with its accompanying waste of time and energy. The general purpose of the instructor is to assure an understanding by pupils of "what next, and why?"

It is well, also, at this time to relate very briefly the new work to that which has immediately preceded it. For example, suppose that a chemistry class has just been working a series of experiments in which it has become very evident that air has an active gas called oxygen in it. The class is now about to prepare oxy-

gen from potassium chlorate using manganese dioxide to hasten the reaction. The instructor reminds the class that it is time to get better acquainted with the gas which apparently was responsible for most of the chemical activity of air. It is inconvenient if not impossible to extract this gas from the air in the ordinary laboratory, but it may be obtained easily in considerable quantity by heating a mixture of potassium chlorate and manganese dioxide. The specific directions for performing the experiment should then be studied, and the laboratory work undertaken. This introductory discussion may take place at the latter part of the previous classroom hour, thus saving all of the laboratory time for laboratory work.

One difficulty at a time for beginners in new and unfamiliar studies means the use of exercises simple in the thought and manipulations required. In choosing apparatus the simplest forms which give satisfactory results are always to be preferred.[1] From the "known to the unknown" necessitates the use in qualitative exercises of what the pupil has already learned in preceding laboratory work, and in the wide range of experiences outside school. These experiences repeatedly invoked enable a ready understanding of new phenomena, and whatever is now for the first time to

[1] In the electrolysis of water, for example, test-tubes placed over two simple forms of electrodes will suffice in place of the expensive Hoffmann electrolysis apparatus. The attention of pupils is not then diverted to the apparatus employed, and away from the phenomena and the conditions these involve.

be learned under the fixed conditions of experimental work. They likewise explain and make significant what has before been unorganized knowledge.

The "write-up" of experiments may come as each exercise is completed, or it may be delayed till the conclusion of a series of related experiments, regardless of whether these are performed by the pupils themselves or by the instructor. In the latter case the teacher should insist upon oral statements of observations and inferences by pupils, with sufficient discussions of the experiments while the work proceeds to enable the pupils later to write worth while notes. These results should be written up for the purpose of recalling, selecting, and properly relating the essential facts involved, and for a concise expression of the connected thought to which these facts have given rise. These papers handed in, credited, and corrected so far as the teacher's time and strength permit, are then returned to the pupils to constitute their notebooks wholly or in large part. In any more or less painstaking review of these exercises in a succeeding class period there is opportunity for the teacher to repeat occasionally some one of these exercises, or to do other related Teacher's Experiments to enrich the instruction, to sustain interest and to provoke further thought. Illustrations may be multiplied as needed. No considerable degree of accuracy or large measure of skill in manipulation of apparatus, and no expensive outfits in apparatus and

equipment, are necessarily involved in this "knowledge-making process."

During the times when the write-up of results of experiments is being carried out, and when the nature of the exercise permits it without endangering the integrity of results, free use of texts and of various reference books in the laboratory by the pupils *still further should emphasize the fact that this time is a study period.* This is the time when a need for facts and explanations from books is most apparent, and the time when information gained from books has its largest value, and when a precise use of an enlarged vocabulary of scientific terms is most natural. It is at these times, too, that pupils most readily learn to use books to the best advantage—one of the most important phases of study-training. Some of the sciences lend themselves to this procedure less satisfactorily than others, but with all the high school sciences various text and reference books may very properly be considered part of the laboratory equipment. Their use during laboratory time under supervision is not only legitimate, but it is fruitful in achieving that major aim of all school work—formation of correct study habits.

It is important to see to it that such science books as are owned by the school are kept in the science department rooms—not in a remote general library. They should be right at hand for immediate reference when

needed. A departmental library is a fine thing where possible; but a wall shelf, or a shelf in an apparatus case in the classroom or laboratory, is sufficient. In a very real sense these books are part of the laboratory outfit. Sectional bookcases are handy for storing reference books when not in use. It is a mistake to allow fear of loss of reference books to interfere with their free use by pupils. The widest possible use, too, of reference texts is to be encouraged rather than restricted. It is part of the instructional duty of a science teacher to be helpful in showing his pupils how to use the library facilities of the department and of the school in general. The use both of the index and of the table of contents of a book should be explained. Certain texts and reference books should at times be suggested to the class for special purposes. If a public library is accessible, it may be well to conduct classes through the reference section, getting the librarian to explain the use of the general catalogue, the scientific periodical index, etc., and to point out the actual location in the reference library room of books upon the various sciences.

In physics and chemistry especially, and in all the sciences of the high school more or less, quantitative exercises such as problems, experiments, graphs, drawings to a scale, etc., may be made to play a double purpose. There is no substitute for the tests which these quantitative requirements make of accuracy in work of pupils, their skill in use of apparatus and appliances,

their conciseness in expression of results. Review of results by the instructor is likewise readily accomplished.

Then, too, the use of quantitative exercises furnishes the teacher and laboratory director a solution of one of the most serious teaching problems connected with science instruction. A reserve stock of these quantitatives should be kept at hand ready to give out at any time to the more rapid workers in a class. Besides the minimum of laboratory work required of all pupils, those more capable and ambitious should be given additional exercises of sufficient difficulty to tax their best efforts. Needless to say these exercises must be of such a nature that the doing of them appears worth while. The more of this extra work done the higher should be the standing of any pupil in the class. By such provisions the duller, slower pupils are not rushed beyond their capacity, and disheartened because they are ever being penalized for natural incapacity and inaptitude. With the principle involved once comprehended by a class, and an ordinary amount of tact and administrative ability exercised in its introduction and use, many disciplinary problems disappear. The laboratory then becomes in reality what it is in theory, a workshop where every pupil in some large degree keeps himself at work because of natural incentives. This is the ideal situation toward which to work. The chief virtue of the project method of teaching depends upon this self-motivation of the worker.

The laboratory manual is, perhaps, the chief single instrumentality employed by an instructor to attain the teaching purposes of secondary school sciences. Especially is this the case in the smaller high schools, and with beginners in science teaching, whatever the science subject taught and however independent of manuals some science teachers in time become. A skilled mechanic does not undertake to build furniture and do cabinet work with a pocket knife, nor is worth while dental work done by use of carpenter's tools. Choice of suitable laboratory manuals precedes and is vital to effective laboratory instruction and laboratory training. A makeshift for a laboratory manual imperils successful science teaching, and impeaches the importance attached to the laboratory side of science instruction.

In accordance with their own experience and that of other science teachers it is the belief of the authors that to secure the largest educational values from a manual *requires that it be used as a guide for classroom practice as well as for laboratory procedure.* Where the instruction in secondary school sciences actually is on a laboratory basis, both the order of topics followed and the amount of text matter for which pupils are held responsible will depend upon the manual employed. All necessary adjustments of a published manual to the particular needs of a class, school, or instructor, will correspond in a measure to the alterations which are needed in a ready-made "standardized" suit of clothes when fitted to an individual cus-

tomer. In either case a misfit entails grief and disappointment. Where the manual in use does not thus offer comprehensive guidance for the course a teacher himself must become the unifying agent, building up around the laboratory work the other units of classroom discussion—text and reference work, industrial or other contacts with daily life, and all oral or written reviews and examinations. It requires a large degree of ability to do this well, but in the hands of an experienced science teacher it yields acceptable results. The beginner of necessity *must use as best he may the tools furnished for his work.*

The type of manual long familiar in high school science teaching has been a rather inexpensive book of directions to pupils for working experiments. These directions are often models of brevity and clearness. But often they lack sufficient appeal to pupils in any requirements of what is well worth doing as problems involving life interests. These manuals at times are made more attractive, and their directions more definite and concise, by use of wisely chosen cuts and diagrams. Tables, too, and various other data appended furnish information, valuable alike to teacher and pupil in connection with the laboratory exercises. But admirable as are many of these manuals whose contents are thus characterized, their use often leaves much to be desired of them. Some teaching ends of supreme importance are apparently not to be attained by their use. The science teacher of beginning courses cannot

understand why he fails in his teaching efforts. Pupils who painstakingly complete these laboratory courses all too commonly fail of acquiring either a scientific spirit, or a procedure characteristic of scientific effort in its application to life problems.

A manual must in the first place lend itself to the conception *that a laboratory hour is a study period.* Under guidance of the instructor it is possible during this laboratory hour to secure methodical and sustained training of pupils day by day in those ways of acquiring knowledge which are characteristically scientific. In the second place, it should provide for such guidance of the pupils that whatever knowledge they may have of the topic under discussion can be assembled through questioning, *and organized about the results of certain experimental work done by the teacher.* Obviously these teacher's experiments must be simple, few in number, and so chosen that a scientific understanding of both the old and the newly acquired knowledge results. These experiments should be such as to arouse and sustain interest, provoke thought, and become centers of instruction. The question list and the experiments so far as these concern the needs of many teachers may be suggestive only, or there may be a mere skeleton of a progressive thought activity the detailed steps in the development of which are left to the instructor. But for use of inexperienced teachers generally it is probable that a manual should furnish a well-considered series of questions and experiments.

It is likely to be more serviceable, and at the same time it is none the less suggestive to instructors desirous of freedom in choices of material and in the order of its use.

In the manual, too, should be incorporated lists of experiments to be worked by pupils only. There should be some few optional experiments for use by the instructor when needed for extending and enriching the instruction, or at times for use by the more ambitious and capable pupils.

Included in the manual should be lists of Exercises designed to serve several ends, one of which is a review of what has presumably been under discussion in connection with the experimental work. Other questions may very properly anticipate difficulties likely to be experienced later by pupils in textbook assignments, thus necessitating a discriminating use of the text and of other reference books for information of a specific character. Problems and other exercises of a quantitative character may likewise be included as an application of what has been taught, paving the way for any suitable quantitative experimental work. In this connection there may be topical and theme requirements, either with or without outlines, and these should include industrial as well as scientific aspects of topics studied.

In so far as there is an experimental basis for it, the manual may appropriate to some extent the development of certain of the theories of science. Although

teachers must ever be dependent upon textbooks for an orderly presentation of the facts of a subject studied, and for a well-digested and well-balanced presentation of scientific theory, there is little likelihood of failure to leave for subsequent discussion in connection with text assignments difficulties sufficient to tax fully both teacher and pupils.

Instruction in secondary school sciences thus is made to center in the manual, and by use of it the teacher is aided in developing the subject topic by topic. The text supplements these science studies, and the number of texts needed by a class is a matter of how many are needed for reference purposes, and in preparation for "quizzes" on text assignments. Every pupil should, however, have a manual for individual use as it is his guide in the primary and fundamental stages of his studies. In connection with its several topics, and especially with classes of beginners, assignments should be made by a teacher of carefully chosen page-and-page references to the text used. This in nowise precludes use by pupils of any other references desired. This insures always a definiteness of assignment not open to question by pupils who for any reason may be indifferent to the work. It constitutes a minimum of text requirements of all pupils in a class. It keeps consistently before the minds of pupils, too, the distinction on the one hand between the study of science from the experiences of life and the phenomena of the lab-

oratory, and on the other from any readings about science as set forth in books.

Summary

1. Need of well-defined plans and purposes in laboratory work.
2. General classification of laboratory exercises.
3. Special difficulties inherent in the science work of large and of small high schools. Unity in aims rather than in methods.
4. Laboratory work as a preliminary study of a topic. Experiments, discussions, and instruction by the teacher during laboratory time.
5. Simplicity of the exercises employed. Uses made of the experiences of pupils.
6. Purposes of the "write-up" of laboratory experiments and discussions.
7. Use of "Teacher's Experiments" both as supplementary exercises, and during class reviews of laboratory papers.
8. Use of texts and reference books during laboratory hours.
9. Quantitative exercises—their nature, their general purpose, and times when used.
   (a) Flexibility of a course to fit varying aptitudes of pupils, and their stages of advancement.
   (b) The laboratory as a workshop.
10. Importance of a manual in the teaching of high school sciences.
    (a) Its use as a guide for classroom work.
    (b) Characteristics of manuals in common use. Lack in results from their use.

11. Two conceptions for laboratory work to which a manual must be adapted.
    Character of question lists, and of the experiments provided as basis of "introductory discussions."
12. Experiments for pupils to work.
13. Ends served by lists of "Exercises" in the manual.
    (a) Uses made of them in connection with text matter.
    (b) Purposes of problems in this connection.
14. Uses of the manual in teaching the theories of a science.
15. Uses of a text in connection with a manual.

CHAPTER III

WRITTEN WORK OF THE LABORATORY, AND THE KEEPING OF NOTEBOOKS

To designate notebooks as one of the necessary evils of teaching is an inadequate conception of their worth. On the other hand, a wholly fictitious value is easily given them. Many a teacher, slaving over the mass of written matter that is ever accumulating from his classes in spite of his best endeavors, would abolish notebooks as the only solution of the problem they present. As a means to an end the written work required of pupils presents to teachers no new problem. It is largely a question of whether or not one shall be master of the means at hand for accomplishing a desired end, or whether the end shall become obscured by the means employed. A proper conception of the purposes of notebook keeping, and of the limitations that must be observed by the teacher in the use of notebooks, should make it unnecessary to become a slave to "reading papers" notwithstanding the large amount of written work required for teaching efficiency.

It is foreign to our purposes here to enter into any discussion of details of keeping notebooks, and of the forms best suited to different science branches in high

schools. Much such information helpful to beginners in science teaching is to be found in published laboratory manuals. Most teachers sooner or later formulate plans of their own especially suited to their personal views and their teaching conditions. It is worth while, however, to discuss in this connection some general principles applicable to all secondary school sciences and to all teachers.

In the teaching processes of the public schools there can be no substitute for the written work required of pupils. It demands of every pupil a degree of mental effort in formulating thought, and in giving it concise expression, which is of largest teaching value. In the recitation the pupil's mind may wander far from the subject in hand. In the laboratory he may waste time in play or idleness. But when it comes to producing an *acceptable written account of what he did, and saw, and thought about it,* the demands made of him must be met. A chief virtue of the requirement of keeping a notebook is that it demands of every pupil an actual consideration of the work in question. It offers also the best possible opportunity for a teacher to learn the mental attitude and readiness of individual pupils in a class, their difficulties in grasping thought relationships, the extent of their vocabularies, and their earnestness of effort. Careless and hasty ways of expression, of observation, and of inference are strikingly apparent to a discerning reader of the written work of pupils.

In the review and correction of notebooks and other written work handed in by pupils, the first and foremost end to be attained is such an insight into the manner of thought and the mental state of those whose written work is reviewed day by day *as shall suggest what teaching procedure with them is likely to be most effective.* Misspelled words should be noted, and grades may be assigned. But these corrections are of secondary importance to the determination by a teacher from such papers as come under review each time *what seems to be the next step in the teaching procedure for the class as a whole,* and what the most helpful course to pursue with those whose papers reveal need of special assistance.

This requires, of course, that papers handed in shall not be allowed to accumulate. So many of them as may be considered necessary should be reviewed, and all papers so far as possible should be returned to the pupil before the next class period. The demands of the written work are then fresh in the minds of the pupils, as are the difficulties experienced by them. The explanations given by the teacher to clear up any and all such difficulties meet a conscious need on the part of those whose written work was faulty. Teaching of the most vital sort is possible at these times when the significance and the accuracy of results of the laboratory work are under discussion. The use of this written work from the laboratory as basis for instruction gives it the proper perspective in the teaching process in

the minds of pupils. Its requirements and its understanding are fundamental in the mastery of the sciences studied, not merely incidental and of the nature of "busy work." Any review of papers made after long intervals possesses little or no interest to pupils beyond noting what grades, if any, are on the papers.

As soon as a record has been made of papers handed in (or not handed in), and a certain few of them have been selected by the teacher for correction, the others may at once be stamped "Not Reviewed" and distributed in file cases for the pupils when they come to class next day. This stamp mark relieves the instructor of responsibility for any errors which may appear in a paper, and is notice to the individual pupil that there is need of careful attention during the discussion of the laboratory work in the succeeding class period so that all errors in his paper may be noted and corrected.

Copying any poorly prepared papers to improve their content or their appearance is largely a disciplinary measure. Its instructional worth is of doubtful value. In the affairs of men as a rule measures must stand or fall as first presented. The next day or the next hour has its own duties that should not be interfered with by attempts to "make good" on past delinquencies. This in nowise means that in teaching as in life affairs generally these "duties" may not be and at times must be the reviewing and recasting of what has before been attempted, but what was so poorly done as to demand

redoing. Removal of faulty construction, and its replacement by what is perfect in workmanship, is the rule in engineering and architectural enterprises even as it should be in the building of mental and moral natures. To substitute for what is not "good" that which is "better" is the essence of educational effort. But instructors should not degrade what is supposedly constructive, and intended for betterment, into a time-wasting procedure.

Much of the crediting on laboratory record books of papers handed in, together with all stamping and filing of papers to be returned, can be done by pupil assistants. Frequently where it seems unnecessary or is impossible for the teacher himself to read all the papers, the chief objects of the written work are attained where corrections of one another's papers are made by pupils in class. Each answer as read from a paper can be criticized by any member of the class, and when necessary by the teacher. The answers can be graded one after another by the pupils having the papers. Since pupils very commonly have an exaggerated notion of the value of grades, it will be well to get the papers back to those who wrote them, and to take a few minutes to allow any protests of the grading when thought unfair.

No one but the instructor, however, should review and correct the selected papers from which to gain information and suggestion for the next day's teaching. Whether grade marks are assigned or not to these pa-

pers, their review should be done as carefully as with the formal test papers from examinations, and grades should be recorded in a laboratory book for the instructor's use. Though the educational value of preserving the written work of the laboratory be considered in itself as negligible, other considerations make a methodical painstaking keeping of notebooks important. Wholly aside from any possible value for review purposes, a carefully kept notebook in any science branch is ever present evidence to pupils *of the continuity, organization, and content of the course.* The pride taken in having a complete notebook is no mean factor in a sustained interest in any science subject. As a matter of discipline in order to secure the necessary sustained effort throughout a semester or year it may at times be necessary to resort to the requirement, "No book, no grade."

As conditions permit, it is very helpful to go over their notes with certain pupils individually, giving each pupil a few minutes for consultation at his own seat or beside the teacher's desk. The good features of the pupil's work can then be complimented, his errors tactfully corrected, and suggestions of a general nature made as to possible improvement. At the same time valuable information will be gained by the instructor concerning the success or failure of his method of presentation of the subject taught. This consultation on notebooks can usually be done best when the class as a whole is busy writing notes on recently completed

laboratory work. The personal contact between teacher and pupil while considering the notebook together may be made an invaluable teaching influence. It should be cultivated tactfully at all times, and it is especially valuable during the early part of the course when pupils most readily get into right habits of notebook keeping.

With the ends of notebook keeping such as set forth above, there is no need for "reading notebooks." Each day's work is cleared up as the work progresses, and the accumulated written work from the laboratory shows on the face of each set of exercises whether or not papers have been corrected by the teacher. During the first weeks of any semester, it is well to call in all the notebooks several times for the immediate purpose of noting whether or not the directions given for notebook keeping are being followed out, and whether the papers are preserved as required. Where all notebooks are required kept at all times in the department, they are always available for inspection by the teacher, and are never forgotten or left at home by the pupil. This latter plan requires, of course, that all work on the notebooks be done in school.

Shiftless ways in written work, and all slovenly habits are too serious a matter to be tolerated. The sooner remedial measures are applied where needed the better. Careless and untidy work, illegible writing, poor spelling, lack of punctuation, and disregard of directions as to form and appearance, are matters

of importance and require attention though neither a test of the pupil's knowledge of the science subject nor any just basis for a grade in it.

Summary

1. Notebooks as a means to an end.
2. Details of various forms of notebook keeping.
3. Substitutes for written work setting forth the results of laboratory experiments and instruction.
   (a) Knowledge of individual pupils given through it.
   (b) Guidance furnished by laboratory papers for later teaching.
4. Return of papers. Their review in class, and the teaching opportunities in such reviews.
   (a) Stamp markings on papers. Grades on papers reviewed.
   (b) Rewriting of papers as a disciplinary measure.
   (c) Pupil assistance in handling and grading papers.
5. Review of notebooks by teacher.
6. Training for habits of good "form" in notebook keeping.

CHAPTER IV

LABORATORY ARRANGEMENT AND EQUIPMENT

"Costly thy habit as thy purse can buy" may at times express the thought of a taxpayer as he inspects modern laboratories and their equipment in some of the larger secondary schools, and again when he audits bills for laboratory supplies and upkeep. In marked contrast to this, however, the equipment and supplies of the smaller high schools oftentimes will be found wretchedly inadequate for the teaching undertaken. Oftentimes this pinch of poverty in the science courses like that not infrequently found in the tenement house districts is directly traceable to wastes resulting from ignorance in making purchases, and from shiftlessness in care of what has been purchased. Liberal treatment by superintendents and school boards may be won or lost to science teachers and their successors through competency or incompetency in use and storage of science apparatus and supplies.

Both school architecture and school furniture are now so fully standardized that in cities and larger towns science teachers are largely spared responsibilities for the arrangement and equipment of laboratories and classrooms. But there are yet many schools in

which science is taught under the heavy handicap of ill-advised furnishings, and where available funds for betterments are so limited that small outlays to improve the teaching service assume an undue importance. It is chiefly with the needs and the teaching conditions in these smaller high schools that we are here concerned since the special teacher for a single science subject in any large well-equipped high school is likely to know better than can be told him what his particular teaching conditions require. In the smaller high schools where one teacher has, it may be, all the science subjects, the teaching problems are entirely different from those of special teachers in large high schools. Nevertheless, economy rather than waste applies equally well to all science teachers, and is as applicable to their time and energy as it is to expenditures for apparatus and supplies.

From time to time science teachers are called upon to consult with architects in connection with location and arrangement of laboratories in new school buildings. There are details of construction essential to efficient laboratory service which are likely to be overlooked save in those cases where a specially trained school architect is employed. One of these items which is of much importance is a good arrangement of rooms as "floor plan" for the science department. The type of arrangement in which the rooms used for the science subjects are strung out in a long line is strictly to be avoided. Such a scheme usually results from

an attempt to use as laboratories rooms designed for classrooms.

The rooms of a science department should be grouped, centering preferably around supply rooms. There should be direct access from the supply room into each of the other rooms. It should never be necessary to go out into a corridor to get into another science room.[1] Valuable time is wasted in carrying apparatus back and forth, and none know better than science teachers themselves how many such trips there are. If made often during class and laboratory periods, room control and class interest are both risked by these absences of the instructor. For most sciences a small inside dark-room is desirable.

Since the walls which sustain the weight of the superstructure and condition the groupings of science rooms rise from the foundations of the building, it is very necessary to have any desired arrangement of science rooms incorporated into the general plan at the very first, especially as concerns plumbing, gas supply, and electric wiring for these rooms. The school architect may not fully appreciate the need for greatly increased demands for plumbing facilities in laboratories, especially in the chemical laboratory.

Building conditions wholly unsatisfactory must at times go unchanged because of circumstances, and various makeshifts must be endured. But well-lighted,

[1] See Appendix B for a desirable floor plan which lends itself to a variety of modifications.

dry, airy and cheerful rooms only are desirable for science laboratories. Basements, attics, unused storerooms, or other unsuitable quarters presume that high school pupils will profit from their science subjects in spite of school conditions rather than because of them. With a laboratory looked upon not only as a workshop but a study room as well, the physical conditions there should be among the best which the school building affords. The furnishings, too, should be substantial rather than showy, and so designed and constructed as to be durable, showing when properly used relatively little wear from long service. Nothing dilapidated and run-down is to be tolerated in connection with furniture and apparatus. Fortunately the serviceableness of furniture and apparatus is not in any considerable degree conditioned upon its appearance and cost.

No attempt is here made to enter at length into details of equipment for teaching the various secondary school sciences. The number of science subjects, and the special equipment these demand, makes such discussions out of the question here. However, there is enough of conformity to types, and of tendency to standardize essentials in high school sciences, that equipment may be considered more a matter of extent than of kind. So complete in design and appointments are standardized laboratory fixtures purchasable ready-made in the market, that the question for consideration concerning laboratory furniture is the relative cost and excellence of the output of factories specializing in

laboratory furniture on the one hand, and what may be had as home construction on the other. Cuts and specifications such as are to be found in catalogues of manufacturers of laboratory furniture may be consulted to good advantage whatever the source whence the furniture may be obtained finally. Oftentimes economy of space is as important as original outlay for furnishings, the floor space set aside for science in school buildings often being inadequate. Proper allowance of working space for pupils in a laboratory contributes to better discipline as well as to greater carefulness and fewer accidents in the use of apparatus. Suitable passage space between pupils at work at adjacent tables must always be provided. (See scale drawing of one arrangement in Appendix B.) An adaptation of standardized specifications in some cases may be more satisfactory than furnishings from original plans.[2]

Perhaps no one waste in connection with laboratory sciences in high schools is greater than that in connection with the misuse and lack of care of apparatus already purchased. Oftentimes this waste is directly chargeable to inefficiency and shiftlessness on the part of a teacher, but not infrequently it is due to lack of suitable storage and repair facilities. Teachers should

[2] The cuts of Appendix B show some serviceable laboratory furniture designed especially for use in small high schools where both economy in space and in outlay are important considerations, and where a maximum of serviceableness at a minimum of necessary cost must be attained.

not be held responsible for the proper care of apparatus where ample and suitable storage is not provided. Cases and closets for exclusive use of laboratory outfit and supplies constitute a first consideration in equipping rooms to be used for science teaching. Science teachers only can fully appreciate the convenience of and necessity for it. The amount of storage space required is large, especially where several sciences are to be taught. To find expensive electrical and other apparatus "stored" on window sills and side tables, and to see chemicals whether in bottles, cartons, or packages crowded indiscriminately upon the shelves of dark closets, is indicative of lack of self-respect on the part of a teacher as well as culpable negligence and waste of public funds on the part of school authorities. The disorderly arrangement of poorly labelled chemicals may be decidedly dangerous because of the increased chances of error in selecting substances for experiments.

Whatever type of laboratory table comes under discussion, a solid well-built frame, *and the best top attainable,* constitute the essential features. If wood tops are used for lecture tables in chemistry, and in other laboratories where liquids are likely to be spilled, they should be at least one and three-fourths inches thick, and so dovetailed, glued, and bolted that no cracks will ever open in them. This necessitates the use of lumber thoroughly seasoned, and so finished on top and edges that no liquid can be absorbed into the

wood. Table tops finished a dull black by treatment with chemicals, making them "acid proof," are preferable by far to highly polished and varnished surfaces. (See Appendix B.) In larger schools with large use made of chemistry tables by numerous laboratory sections, table tops of more durable material than wood are desirable. They are more economical in the long run.

Preferably no openings should be cut in the tops of tables unless for gas jets, and except possibly in the chemistry laboratory all sinks should be placed along the walls within easy reach of pupils at work. This eliminates much unsightliness even in well-kept laboratories. It costs less for plumbing where pipes can follow the walls. Where sinks are in the tops of tables there is likely to be an unsightly crack around the edges of the sink top, and a spattering of water on the table top from the faucets. A lesser evil is to have the sinks placed at the ends of the tables. Small jars well glazed within and without may be kept on the chemistry tables during a laboratory period into which all waste solids and liquids may handily be emptied. When filled these jars can quickly be drained of their liquid contents at a sink, and the solids dumped into a large waste jar for the janitor's care. In large chemistry laboratories the sinks may drain into a lead-lined or alberene catch basin having an outlet pipe standing six or eight inches above the bottom of the basin, and suitably capped with a strainer. In this

way all acids and alkalies are sufficiently diluted to lessen materially any corrosion of the drainage pipes. The liquid in this catch basin must of course be flushed out every time after use. (See Chemistry, p. 277.)

For microscope work in Botany light preferably should be from north windows; in Physics direct sunlight through south windows is desirable. A good quality of window shades should be provided, sufficiently opaque to darken satisfactorily any room desired. Gas and electric lights now commonly available should be arranged wherever likely to be needed when any school building is erected. There must be gas connections on the chemistry tables; in other laboratories the gas may be on the tables at one side of the room near sinks. The same classrooms and laboratories may be used in common for different sciences, especially when under direction of the same teacher. Even the room set apart for a chemistry laboratory may be used for other classes when not needed for chemistry, in case it be sufficiently large and well-ventilated and properly seated.

But when any such use is made of the laboratory the greatest care must be taken lest pupils not in chemistry classes injure themselves or their clothing by meddling with acids or chemicals at hand. Pupils who are regular members of laboratory classes are supposedly trained not to molest materials, but other pupils using the room are peculiarly likely to be tempted to play with the chemicals. The greatest

alertness on the part of the teachers, and considerable tact in enforcement of rules forbidding any tampering with apparatus and materials, will be required in order to avoid deplorable accidents.

Small deposit fees collected of pupils at the time of registration for such laboratory subjects as chemistry provide a sinking fund for repairs and replacements which are made necessary by reason of accidents and various laboratory exigencies. As a rule these moneys should be expended only upon request of the science teacher, and any such charges must never be so heavy as to be a hardship for pupils taking science subjects. Such a fund is extremely valuable, too, since it can be used on short notice as needs arise without necessity of placement of an "order" with the purchasing department. When ice is needed, for example, a boy can be sent for it with the money from a cash fund on hand. No amount of foresight provides for every item of possible expenditure in the makeup of a year's budget, and a petty cash fund becomes a necessity. A refund made to pupils at the end of the course as supplies are turned in, serves as a check on the carelessness of pupils as well as to provide a fund. The charges are best collected at the school office at the beginning of a semester, and refunds should be made there to pupils on basis of report from the science instructor of deductions to be made. Since generally it is unwise for any science instructor himself to collect and disburse moneys from pupils, all emergency

expenditures should be made through the school office *but always on order from the science teacher only.*[3]

In schools where annual outlays for science apparatus and supplies are considerable, a budget system for all the sciences is desirable. An itemized list of needs for the ensuing year should be prepared for the school authorities early every spring. This makes possible a scrutiny of items with view to economy in all outlays made, as well as serviceableness of material purchased. In lists submitted to dealers in supplies there should be provision that bids are to be "upon all or any part" of the list. Selections can then be made more advantageously. Presumably but not necessarily choices made will be the lowest bids on items. Usually where the consideration is but a slight difference in prices, it is better not to scatter these purchases too much. It involves separate shipments and deliveries of goods, and the opening of accounts with different firms.

[3] One satisfactory method of collecting such a fund, especially with larger classes using extensive outfits, consists in taking receipts from each pupil at the beginning of a semester for one complete list of apparatus in good condition. Printed slips fitting a loose leaf pocket ledger are handy. These slips should contain an itemized list of the apparatus usually issued, and the price of each article should be carried out to the right hand margin. If extra apparatus is taken out of the stock room by pupils during the semester, pupils should sign a "Day Book" slip for each piece. A pupil assistant can copy such daily slips to the proper ledger pages. At the end of the semester all pupils return such apparatus as they still possess for credit, and are charged for missing or broken items. Their bills should be paid at the financial office of the school, and the amounts thus retained constitute a "Science Fund."

Summary

1. Characterization of science of smaller high schools. Causes for it.
2. Kind of rooms suitable for science teaching. General character of furnishings.
3. Relative merits of "ready-made" and "home-made" laboratory furniture.
   (a) Plans for furniture in relation to space available.
   (b) Cuts of serviceable laboratory furniture. (See Appendix.)
4. Provision for storage of apparatus and supplies.
5. Laboratory tables. Finish for table tops. (See Appendix.)
   (a) Location of sinks.
   (b) Disposal of wastes of chemistry laboratory.
   (c) Gas supply.
6. Location of botany and physics laboratories. Uses of same room for different sciences.
7. Fees for sinking fund. Their collection and expenditure. A budget.

CHAPTER V

TEXTBOOKS IN SCIENCE TEACHING, AND THEIR PURPOSES

In the earlier stages of development in a new field of knowledge practically all the facts in regard to it are in possession of a few individuals. As a rule these facts are few in number, and there is little of logical relationship between them. As more and more facts become known, and their inter-relationships become realized, speculation as to the probable underlying causes of various groups of phenomena is attempted. As the more promising hypotheses attract attention, much work is done in attempts to sustain or to disprove them. Such of these hypotheses as are found in accord with the facts of all situations where they are applicable are accepted as working hypotheses, and become established as theories. A great body of knowledge by this time will supposedly have been assembled and systematically grouped in accordance with these theories. At this stage we have a full-fledged science, and it is now time for textbooks to be written in order to bring before students, whether as beginners or those more advanced in the subject, a selected body of facts and theories together with their applications in the affairs of life.

Without such a presentation of what has been learned by others, a beginner as a student in that field of knowledge would of necessity have to rediscover and reorganize all that his predecessors in that field had slowly and painfully wrought out and made known. He has now, so to speak, the advantage of maps of the field as made by them. Such is a major purpose in having a textbook. It brings to a student the essentials of a subject as these have been gained and evaluated by others, with facts pertaining to the subject presented it may be in an order partly logical and partly chronological. These facts are put together upon a framework of theory, and to this is related such applications, illustrations, and exercises as make the subject more interesting and more profitable to the student.

In our consideration of the function of laboratory work, much emphasis was placed upon the value of first-hand efforts to acquire knowledge, but that process in its very nature is slow and laborious. In spite of the unexcelled merit of laboratory work as an exercise in mental training, only a modest portion of any well-established science can be learned first-hand by the student of to-day. A great proportion of what is considered necessary to learn in any field of science must come to him in other ways, and much of it by necessity from an intelligent use of well-selected texts.

Most science teachers are fairly well agreed that the use of a text should follow rather than precede intro-

ductory laboratory exercises. After a class has gained some first-hand acquaintance with a topic by contact with it in the laboratory, and the relatively meager amount of knowledge thus gained has been discussed and written up, students should be directed to a good textbook to get the benefit of what has been learned upon these topics by others, and what is thought about them by the best authorities. From these textbooks students learn what uses are made of this scientific information, and how it may concern us in our homes and in our life careers. The text should contain stimulating exercises, too, in connection with each topic so that the extent and definiteness of one's knowledge of a subject can be tested by attempts to apply it to those new conditions set forth in the various situations and problems given. In this way the essentials of these matters become fixed in memory, enriching life with much that is of interest.

With this method of allowing the use of a text to follow the laboratory attack upon new material we have an excellent guide as to what parts of the text shall be used and what parts omitted. Texts often are compromises built to suit "many men of many minds." In consequence nearly all texts contain more material than can be even apprehended much less comprehended by any one student in the time usually available for a course. Some of the poor results complained of in science teaching may often be accounted

for as due to efforts on the part of teachers to cover too much ground. An intensive consideration of fewer topics commonly gives better results in science teaching.[1] With a well-prepared outline of topics to be taught, and with a laboratory course adapted to this outline, a teacher is in a better position to select portions of a text in supplementing other sources of information upon any topic.

A suitable distribution of the theoretical parts of a subject in a textbook for use by beginners necessitates thoughtful consideration when preparing an outline of a course. If a text must be used which does not conform with an instructor's ideas in this regard, it often is well to follow an outline, using the textbook presentation of any theory after enough facts pertaining to it have been accumulated to warrant discussion of it and its applications. There is no serious objection to use of an outline which has an order of topics unlike that followed by the text used. Only lazy and incompetent teachers slavishly follow even the best of texts. Beginners in teaching, however, may safely venture to do the thing which seems best to them only after due consideration, and whenever possible only after consultation with successful teachers who are more

[1] A recent move on the part of the American Chemical Society, which has a committee on Chemical Education at work on *A Standard Minimum Outline for High School Courses in Chemistry* is suggestive of like efforts on the part of organizations in a position to do similar work for other sciences.

experienced. Boys and girls rather than books are to be taught, and the work to be of value must be alive and original rather than dead and imitative.

In a presentation of the theoretical portions of a science the teacher if at all experienced should usually give to the class the first discussions of it. He can adapt what is to be taught to his pupils, amplifying the teachings of the text as necessary. Study of the text then follows profitably since in his exposition of theory the writer of a science textbook supposedly employs carefully chosen words and concise forms of expression. In language suited to those who are to use the book, he has endeavored to set forth scientific beliefs which are generally accepted.

The organization of the subject matter of a text as a whole by the author requires a relatively advanced stage of mastery of the science concerned. It presupposes a large amount of material to be considered, much of which cannot for lack of space be incorporated into a textbook. This excludes many minor relationships inferred directly from phenomena, and much other first-hand information. Theoretically, then, *a text is not to be used by beginners as a primary source of information upon any topic.* It may be supposed to tax the ability of advanced students in its particular field in an endeavor to master satisfactorily its generalizations and applications. It sets forth a last stage in the organization of knowledge into a science. It uses the theories and laws of that science as its frame-

work. These mark the culmination of man's advance in that particular field of learning.

Teaching experience, however, warrants sustained efforts throughout a science course to have beginners comprehend something of the theoretical side of science. The time allotted any one school science is all too short. Every means at hand for its mastery must be used, and it is upon the text very largely that pupil and teacher must rely for a clear-cut condensed presentation of scientific theory. Much of utmost worth educationally may be learned in any of the sciences with little or none of the related theories, but it is knowledge without organization. Because of its fragmentary character it lacks significance and it is soon forgotten. The special difficulties of the theoretical in science makes necessary much of discussion, illustration, and amplification in class periods. As a matter of teaching procedure, and because of difficulties attendant upon the growth of true conceptions of the abstract in science, it is wise generally to teach its theories a little here and a little there. This is best done in connection with those particular facts which serve as a basis for any theory. It is usually unwise to attempt the mastery of the theoretical portions of the science apart by themselves.

Another important use of the textbook, and one for which it is indispensable, arises from the systematic continuity and completeness of its discussion of topics. It can be assumed that an author has maintained suit-

able proportions in these discussions. From them the learner gets a right conception of the importance of each topic, and of its relationships to the subject as a whole. However unobtrusive it may be to the reader of a textbook, it is presumed that a proper arrangement and balance of the important features of the science would appear in any outline made of text matter, and that all minor points and illustrations of the text would fall naturally into their places in such an outline. There will be perchance many topics considered in a high school science where the text is sole source of information. There will be times, too, when a preliminary reading of the text and of other books may be necessary to give "point" and purpose to experimental work planned, the text furnishing a better introductory discussion than could otherwise be provided.

The order of topics may differ widely in different texts in the same science, but their relative major and minor values should remain fairly constant in all. A text lacking an organization of matter which lends itself to a systematic outline lacks seriously if not fatally in teaching value, and makes the mastery of its subject matter unduly difficult for pupils. Such considerations as these should govern one in the selection of textbooks. Systematic and orderly treatment of subject matter, natural transitions, gradual increase in difficulty, frequent application to the new material of what has already been presented, relatively late presentation of theoretical matter, good summaries of chap-

ters, thought-provoking exercises, problems graded in difficulty, and a good index are some of the major things to seek.

A most important feature of a good text is its illustrations. The eye takes in facts and their significance as set forth in pictures much more readily than it does a message from a printed page. The "legend" accompanying an illustration should furnish wherever possible specific information of value additional to text discussions. Profusion of illustrations of superior teaching worth are supplementary to first-hand laboratory studies, too, and a substitute for lantern slides and educational motion pictures in high schools lacking equipment of this nature.[2] To show connections of parts in apparatus set up, the structural relationships of plant growths and the working parts of machines, cross-section drawings serve better than photos or perspectives. Cuts are not to be "just pictures," serving to embellish the pages. They should be so chosen as to have in themselves large teaching values, setting forth the teachings intended more concisely and more completely than could be done in words using the same amount of space. The "Exercises" at the close of the several chapters, whether in connection with or in lieu of a "Summary," serve chiefly, it may be, for reviews. But they should include, too, thought-provoking questions, calling attention to relationships and

[2] The Society for Visual Education furnishes information of value to science teachers on application.

applications likely to be neglected or overlooked, and requiring the use of the text as a source of information. Numerical exercises furnished by the text may very properly be worked out during laboratory hours under the supervision of the instructor. As quantitative exercises they are of the nature of applications of the teachings of the text. They serve not only as a test of ability to apply these teachings, but because of the need for an understanding of the relationships involved in their solution they have large teaching worth. Cuts of apparatus, assembled for use in connection with descriptions of experiments whose results are given in the text, often convey much desirable information more clearly and concisely than is possible by use of formal text narrative.

All these various uses and modifications of form in text matter are wholly compatible *with the use of a text during laboratory time as a reference book* whence to get information on specific points. To make possible the largest usefulness of a text it must have an "Index" by means of which the contents of the book are made available with all the readiness and completeness characteristic of the best reference books. A text lacking a good index is of little value in training pupils to be self-reliant in study. These uses of a textbook as a source of information, taken in connection with what is presented by the teacher in class periods during review of laboratory papers, narrows the amount of matter and range of discussion of its content in any

succeeding class period. While pupils are later held to strict account for a mastery of "all that the text gives," much of what is in the book will already have been so fully presented as to require little further consideration in class. For those pupils who learn more slowly than others the text provides a desirable repetition of instruction given by the teacher, or made known in the laboratory. There is no time limit upon the use of a text by such pupils, and it can be consulted again and again. To the slow but earnest student the use of a text is a necessity, however brilliant and effective the instruction afforded by classroom and laboratory may have been.

Summary

1. Nature of textbooks in science. Necessity for them.
   - Early beginnings of any science.
   - Textbooks in relation to the mature development of a science.
   - Values of texts as a summation of much experience presented in an orderly manner.
2. The place of a textbook in a science course.
   - Its use with reference to laboratory work on a topic.
   - Use of selected portions only. Attempts to cover all matter in a text.
   - Portions of text to be used in connection with instructor's outline of course.
   - Place of theoretical portions with reference to the fixed order of any text.
   - The textbook as the best means for grasping scientific theory.

3. Valuation of a good textbook with regard to a well-balanced treatment of its topics.
4. Criteria in selection of a textbook as regards: (a) orderly presentation; (b) natural transitions; (c) correlation of topics; (d) late presentation of theory; (e) good summaries; (f) graded exercises; (g) a good index; (h) value of cuts and other illustrations.
5. Use of the text in connection with laboratory work.

CHAPTER VI

CLASS MANAGEMENT

It would seem that little difference should exist between educational ends sought and teaching procedure followed whether classes under instruction be in the sciences or in other branches of study. A clear perception of what these ends are is indispensable to all teaching success alike. *However, it is in the ways of accomplishing these teaching ends that the success or failure of beginning courses in science largely lies.* Departure from a teaching procedure usually followed in other subjects becomes so marked that the special procedures found by experience to yield best results in science teaching come quite largely to dominate the teaching situation. Instruction in science should be based very largely upon knowledge gained first-hand through both experience and experiments. And it demands of the science teacher a conception of class procedure peculiar to itself in order to avoid having the work degenerate into a mere quiz upon statements concerning science such as are to be found in books.

The class period [1] in part should be given over to an enlargement, organization, and enrichment of first-

[1] See Introductory Discussion under "Teaching Cycle," p. 118.

hand knowledge of scientific facts and phenomena previously acquired by the individual pupils. It should be made a thought-provoking period, for which the use of texts must be supplementary rather than preparatory. *It is a time for intensive thought-effort on the part of every pupil in the class under guidance of the instructor.* It has primarily to do with relationships of facts bearing upon the topic under consideration, whether these facts were gained from experience, from teacher, or from books. It is a time to call attention to various related phenomena, and to let the class consider how the facts or principles recently acquired apply to and explain these "problems" brought to their attention.

The class period is indeed a time for teaching. But the instruction given seeks primarily to unify and weld together a "class knowledge" out of the scattered information possessed by the different pupils. It is the teacher's part as an instructor to fill in the existing gaps in what is known by the class; to supplement, to amplify, and to enrich this knowledge. Any historical setting of the subject in hand is best given by the teacher at this time. But, regardless of any fund of knowledge that the instructor may possess, it assuredly is not a time for dumping this information upon a class *just because the instructor has the information to give.* There must have arisen some apparent need for it, some use that can be made of it, before its full teaching value is attained. In the routine work of

secondary schools the formal lecture period of the college classroom is out of place.

The quiz, too, as a means whereby the instructor may learn how much (or how little) individual pupils know of any topic, and how well they may have prepared upon any assignment, and where further assistance is needed for the class as a whole, should not become a mere pumping process characterized by neither constructive nor progressive thinking. The quiz is essentially individual in its demands, while the class period is a time rather for team work wherein every one of the class keeps step.

The management demanded for securing a unity in class thinking must, of course, be varied. The factors involved—teachers, pupils, topic, and the conditions under which instruction is given—are all variables. But some general principles are worthy of emphasis in this connection.

Of one thing teachers are well assured, viz., that their pupils will think. They will do that regardless of a teacher. The class problem is *to control and direct their thinking* so that desired teaching ends are attained. This does not at all imply that pupils are equal in their ability to do sustained intensive thinking, but rather that during all the class time *the thinking of every member of the class* is centered upon the topic under consideration. This involves undivided attention from every one, and thought-effort that is progressive. This must be true, however diverse in

definiteness and comprehensiveness the thinking of individual pupils may be.

To the teacher of secondary school sciences more, perhaps, than to most other teachers, comes the opportunity, the responsibility, the necessity, and the difficulty of securing constructive class thinking. The material is abundant and of a character that makes a strong appeal to a wide range of youthful interests, inciting to thought activity. But for pupils to acquire *a consciousness of power to organize thought material* requires time. There is a mass of raw material of facts and phenomena to be brought together by the pupil, and any mastery of the necessary framework of theory is a slow process. Even in the elementary phases of a science the allotted time for any one science subject is likely to be altogether too short.

As the facts and theories of any science are used day by day under the teacher's direction, it is not primarily for the mastery of science by scientists in embryo. Rather, the teaching purpose is to establish and maintain teaching situations in which shall be developed thinking men and women *with a scientific attitude towards the affairs of life.* Men and women are needed who desire the facts concerning any problem engaging their attention, who are capable of acquiring and interpreting such facts as bear upon any case, and who can plan and execute in accordance with their understanding. Class management then seeks to attain more than a mere knowledge of the subject

studied. The material of the science subjects is to be so used that growth in general capability in all the affairs of life is made possible though the subject matter of every one of the sciences studied may be forgotten. Whatever may be the immediate end of college courses in science, in secondary schools the dominant purpose is educational rather than scientific. It is to fit men and women for the ordinary affairs of life rather than to make scientists out of them.

There is no short cut to attain ends such as these. Neither is there any device or scheme warranted to succeed in the hands of any and all teachers and under all circumstances. However, it is doubtful if any general teaching plan consistently and persistently followed affords larger results than the one briefly set forth below:

(I) Let a large majority of the questions asked be thought questions *based upon knowledge supposedly possessed by all members of the class.* This would include preceding class and laboratory work, common life experiences, and lesson preparations as assigned. By varying the form of these questions sufficient emphasis for drill work may be secured for those relationships having the largest measure of educational worth.

Whenever possible let the questions concern cases commonly known to happen, or that may be made to happen before the pupils at the time. Try to get them to apply their knowledge of the work in hand to the

new situations. For example, when a beginning class in chemistry has just been studying the oxidation of iron by heating, let them attempt to find out the nature and action of a "sparkler" [2] which as one of the familiar forms of fireworks contains iron filings and saltpeter as chief constituents. While one cannot always use fireworks to drive home a lesson, the alert teacher will always find something at hand.

(II) Expect and eventually insist upon responses by the raised hand to every question asked, *showing a readiness on the part of every one in the class* to attempt an answer. Withholding the hand is a confession of inability to answer. As question after question is asked, decision on the part of a pupil *whether or not he knows, and whether or not he will offer to answer,* together with the mental effort involved in framing the answer which he may be called upon to give when his hand is raised, maintains an ideal mental condition for teaching. It may be attained quickly, and be continued throughout the class period. The class thought is thus wholly under the control of the instructor, with no time for any thinking by the pupils

[2] Let members of the class have some of the material from a sparkler as they see it burn, catching some of the flying particles on white paper. By the use of a magnet and a magnifying glass they may be able to distinguish some of the original iron and the black magnetic oxide which results from oxidation. The use of the saltpeter must be accounted for, of course, and here they should receive help. Relating oxidation by air to oxidation by an oxygen-containing compound can be made a natural and easy transition. If oxygen be prepared subsequently from potassium chlorate, one can then hark back to the potassium nitrate of the sparkler. This sort of application and inter-relation of knowledge is the very best sort of training.

other than what is demanded through the questioning. With it all is a sustained training in making prompt decisions as to what one knows upon any question, and in formulating quickly into words any knowledge possessed.

Though but one pupil may be called upon to give voice to any one answer required, every pupil in the class has profited by getting ready to give answers. In theory at least every pupil answers every question, receiving in turn the maximum benefit of the class period *as a thought exercise.* Where any answer as given is incomplete or unsatisfactory, other voluntary answers may be accepted in place of it or to supplement it. Considerable tact is required at such times to avoid discouraging the pupil whose answer has been inadequate or incorrect. A kindly treatment of the pupil whose answer requires amendment will suffice, and a request made of another whose hand may be raised to "help out" will carry with it no sting. The teacher's occasional summing up at different stages in the progress of the class exercise rounds out and completes the whole discussion.

Any such plan of instruction is equally applicable in many other than science subjects. But the multitude of relationships among the facts that constitute the subject matter of any high school science, can make its use by the science teacher highly effective. Its flexibility, too, is noteworthy. Questions are readily framed that give opportunity for the slowest and dull-

est ones to do their best, and then again can be made sufficiently difficult to tax to the utmost the brightest and keenest minds in the class. The teaching value of the plan lies, however, in the requirement *that every pupil decide whether or not he can answer every question; if so, in what words to put the answer.*

There is a vast teaching difference between decisions reached upon the pupil's own initiative, or wrung from him unwillingly by reason of insistence of the teacher. Pupils who when called upon are able to answer questions though their hands were not raised, may be asked to explain why their hands were not up, and why they are not working with the class. This is a disciplinary matter, however. Those seeking credit for shallow thinking, soon separate themselves from the others by their failures to answer correctly. A growing self-consciousness of their fault is likely to prove its own corrective.

The art of questioning that keeps alert every member of the class and carries the discussion forward so that at all times the teacher is master of class thinking is, of course, only to be perfected through practice. In connection with this questioning, and furnishing no inconsiderable part of the facts involved in the discussion, is the instruction given by the teacher. No better conditions for effective teaching can be attained than to have minds alert for information the need of which has been made apparent.

For every new topic taken up in the class period the

teacher has recourse for a point of departure to simple laboratory exercises which have been performed by the pupils or by himself. Lecture table experiments performed before the class at the time serve to introduce pupils to what is yet to be discussed, and to make application of what has been under discussion.

Class management of this character lessens materially any need to provide for so much individual laboratory work by pupils in the secondary school sciences. In botany and zoölogy when use is made of the compound microscope, and in much of the work in chemistry, there is no substitute for individual laboratory work by pupils. But the science teacher of the smaller high schools having several different sciences to teach is burdened in attempts to prepare for individual laboratory work, and to clear away after it. The burden often cannot be carried because of inadequacy of apparatus and supplies. With much of the experimental work in every high school science, possibly all of it in some of them, these experiments performed by the instructor will yield largely if not fully all benefits which theoretically follow from laboratory exercises performed by the pupils only. It has been very truly said,[3] however, that when class experiments take the place of laboratory work by individuals, there is likely to occur a separation of the class into (a) those who do not even listen as the work proceeds; (b) those who do not make the mental

[3] Coulter and Patterson: *Nature Study*, p. 52. (D. Appleton & Co.).

effort involved in formulating answers and giving expression to queries arising in connection with the phenomena under consideration; (c) those who do not observe thoughtfully albeit in appearance listening; and (d) those who eagerly endeavor to do all the listening, observing, and answering. Such conditions, possibly all too common, may justly be considered the fault of the instructor, and in large measure unnecessary and impossible with suitable class management.

Summary

1. Need of a clear conception of class procedure.
2. Primary purpose of class periods.
   (a) Use made of pupil's experiences.
   (b) Class periods as "thought exercises."
   (c) Part of the teacher, and conditions essential to fruitful instruction.
   (d) Purpose and procedure in a class quiz.
3. General principle involved in securing unity ("teamwork") in class instruction.
   (a) Relative ability of pupils to think.
   (b) Progress made in constructive class thinking.
   (c) Primary purpose of the facts and theories of science in class instruction.
   (d) Unlikeness of teaching ends in college and secondary school science.
4. A working plan of class management for instructional ends.
   (a) Character of questions. Drills and reviews.
   (b) Purpose of raised hands in reaction to questions asked.

Psychology of procedure followed.
Teacher's part in the teaching process.
Advantage of science subjects in use of this plan.

(c) Flexibility of plan in relation to bright and dull pupils.
(d) Disciplinary measures involved, and made possible.
(e) Possibilities of control of class thought.
(f) The place of laboratory exercises in this scheme.
(g) Experiments by teacher rather than by pupils. Limitations in this.

CHAPTER VII

USE OF PROJECTS IN SCIENCE TEACHING

Confusion in meanings, and much in the way of explanations, necessarily resulted from attempts to limit the use of the word "projects" with its long-established and varied senses to the greatly restricted significance given it in the professional vocabulary of Education. The outcome of these efforts has not been wholly a happy one. The advent of project-teaching has to science teachers meant the elevation into undue prominence of one of the long-used features of science teaching which under name of "Semester Themes," "Term Papers," "Topic Studies," etc., possessed to some extent at least the teaching values now ascribed to projects.

In applications of science to farming, workers in experiment stations and students in agricultural colleges long since undertook such projects as a determination of the effects of varied soil tillage in potato culture, and the nature of diet best for growth of beef cattle or milk production. Engineering students undertook as projects road and bridge building enterprises, studies of drainage and sewerage systems, community water supplies, etc. Chemists, physicists, bot-

anists and others in the various fields of science, as well as business and professional men, housewives and financiers have all had their schemes as "projects" for attainment of desired ends which should be advantageous to them as individuals and to people generally.

There are reclamation projects, city-planning projects, projects in high finance, as well as home-garden projects and similar enterprises. Pupils in general science undertake as projects an acquaintanceship with and identification of the trees of a community, the collection and classification and recognition at sight of various forms of insects or minerals. All these, supposedly have as a common factor *an impelling desire to know, or to achieve,* needing only guidance for the attainment of desired ends as result of sustained and it may be prolonged effort.

The desirability for transfer of such efforts as these from the world of affairs and advanced stages of mentality to the field of secondary education, especially into the teaching of high school sciences, is not open to question. It became an educational movement seized upon by such educators as ever are seeking to hear and to tell something new. But for science teachers too much worth is possessed by projects in instructional processes either to discard or to ignore them. As in the use of quantitative experiments in physics they serve the valuable teaching purpose of keeping profitably employed at all times the more rapid workers among the pupils of a class. In their use provision is

made for a profitable activity on the part of certain capable ones whose tastes are specifically developed in some particular direction. Through judicious use of projects "kept on hand" by science teachers the brightest and most capable of a class in any science may be kept at work at their best without overtaxing the abilities of the less capable by requirements beyond their capacities.

One of the notable characteristics of a project as employed in teaching is the supposed desire of a pupil for the undertaking. On his own initiative its accomplishment in due time is brought about with a minimum of supervision and of assistance on the part of an instructor. Where pupils are told to make selections from a posted list of titles, and to have projects completed at the end of a semester, or other stated time, there is occasion to wonder how much there may be on the part of any pupil of a desire to engage in the undertaking. On the part of a graduate student working out his Master's Thesis an objection of this nature may very suitably be waived, of course. But one is staggered by the lists of projects furnished for use of pupils in general science, and in high school biology. Useful as these may be on occasions to the teacher, and incidentally to pupils, an undue importance is given their teaching value by reason of their being so prominently played up in the body of a text.[1]

[1] The authors forbear giving any "Lists of Projects." However attractive such lists might be to beginners in teaching, most texts and laboratory manuals furnish, or suggest, whatever titles may wisely be tried out.

Ready-made projects at their best are but means towards certain well-defined teaching ends. As agencies in science teaching they are merely incidental to and are not fundamental features in the round of teaching procedure. Properly employed the project is a tool for use by expert teachers; when inadvisably employed its worth becomes matter of uncertainty, if not wholly negative. A razor suitably handled is an admirable tool for the purpose to which it is fitted, but its usefulness as a razor is seriously impaired when used for sharpening lead pencils, and the boy so using it does so at risks to himself.

Because of the many facts involved in teaching science subjects, and the multitudinous relationships between these facts, there is an aspect of project-teaching of major importance for science teachers. For our purposes of discussion it may be designated Teacher's Project in distinction from *projects in teaching.* In these cases the "desire" is in the teacher rather than the pupils. *The achievements sought are excellencies of results in his labors as an instructor and inspirer of youth.* At all times, while he labors in ways wholly practical and common-place, his goal is the fullest realization possible for him of the ideals of schoolroom instruction and training. Every lesson, and every series of lessons, constitutes an undertaking in the planning for which every resource of the teacher is employed—knowledge, method and other professional

training, knowledge of human nature and of teaching situations.

While the lesson plan required in teacher-training courses, and by the principals of some schools of their inexperienced teachers, has features in common with these teacher's projects, there are notable distinctions to be made. The "Plan" is a requirement which must be met under penalty. The teacher's project is an effort initiated by an aspiring teacher himself in order to teach pupils rather than lessons. It is one of a series of teaching stages in which the lesson plan is a component, and withal an important part. Like the plan it represents foresight, with adaptation of means at hand to the accomplishment of desired ends. But it is more than an intellectual effort for organization of material for teaching purposes. It involves enthusiasm and sustained effort to make successful an undertaking. Its success is measured by what is learned by the pupils, and in its nature and use it represents the "acid test" of teaching ability.

Where the "desire" of high school pupils to engage in some project of whose difficulties they are blissfully ignorant is the outgrowth of expectation that by doing this they will avoid other and regular requirements with whose exactions they are conversant, it augurs ill for any large educational values from their efforts. Likewise, when the enthusiasm of an instructor leads to starting out with projects wholesale in his courses, grief attends his undertaking. None better than

teachers know how much easier it is for them to do a thing themselves than to get a pupil to do it well, and carrying through a project to completion is no exception. To start in upon use of projects with a science class, and then never to complete them, may be pardoned once by reason of inexperience, and by reason of ignorance of the labor these involve for a teacher, but all such later undertakings left incomplete convict a teacher of inefficiency. The value from use of projects in instructional processes as in other school work is measured by what is accomplished rather than by what has been started.

So much of woe may attend the efforts of a beginner in science teaching enthusiastic over the use of projects in education, the values of which even under favorable circumstances can never be wholly realized, that it is not inappropriate here to list a short series of "Don'ts" in connection with the use of projects in science subjects of both junior and senior high schools. Naturally these suggestions are for beginning teachers, and have reference to caution to be exercised by reason of lack of experience. In nowise do they reflect upon the value of projects when used advisedly. Supposedly any teacher is to exercise good judgment in a determination of whether or not these apply to his teaching conditions:

I. Don't enter upon the use of projects wholesale, with an accompanying choice (or assignment) of topics for all members of a class. It is the part of teaching

wisdom to begin the use of projects with a few only of the pupils of a class, and then only as conditions are especially favorable.

II. Don't fail to carry to completion whatever is undertaken. *Don't be a "beginner."*[2]

III. Don't neglect the use of projects, on the other hand, by reason of the labor involved on the part of the teacher. They furnish one of the few opportunities in the public schools to preserve and promote individual independence and initiative, while at the same time coöperating and keeping step in a group progress whether instructional or civic. *Remember that great students are made one by one as a product of the skill of master teachers.*

[2] In the social order of to-day the "promoter," and the "organizer," are much in evidence as they "start things." In school work clubs are "started," officers elected, committees appointed, and funds raised sometimes with and oftentimes without wise counsel. The wasted energy of these undertakings is large whatever may be the benefits derived from efforts put forth. But for teachers to turn promoters, and engage in "starting things" which are likely to come to naught is non-pedagogical. The training involved for pupils has a most serious aspect. At the same time it recalls the rhymes from the "Goop Books" (Burgess: Frederick A. Stokes Company):

> Tony started bright and early clearing up his room;
> Soon he found he had to stop and make a little broom.
> So then he went into the yard to get a little stick,
> But the garden needed weeding, so he set about it quick.
> Then he found his wagon he intended to repair,
> So he went into the cellar for the hammer that was there.
> He just began to build a box when it was time for dinner;
> And that's why Tony's father called his son a "good beginner."

Summary

1. Various meanings of the term "projects."
   Restricted use of the term in education.
2. Feature common to all educational projects.
3. Use of projects for flexibility of science courses.
4. Making choice of projects. Their relative importance in the teaching procedure.
5. Special significance of projects of a teacher as "Teacher's Projects."
   Distinction between projects and lesson plans.
6. Woes attendant upon ill-advised use of projects in teaching.
   Three "Don'ts" in the use of projects in class work.

CHAPTER VIII

AN EDUCATIONAL CREED IN CONNECTION WITH HIGH SCHOOL SCIENCE TEACHING

The time once was when individuals formulated or subscribed to declarations beginning with the words "I believe," etc. In these later days when a lack of well-defined beliefs and opinions is painfully apparent in the educational world as elsewhere, one may be pardoned a desire to see this state of non-belief give way to convictions sufficiently positive to endure over a season. From the teaching experiences of the past there has been organized such a body of educational principles and of educational philosophy as taxes the ability of each succeeding generation of teachers to make suitable application of it all. The task of testing out new things in education can be given over to a relatively small body of educational leaders, leaving to those less experienced the settling of such fundamental questions as "What is it to be educated?" and "What is my part in assisting my boys and girls in school to acquire an education?"

In the unending round of "things new in education" one is reminded of the great apostle when, speaking to the Athenians on Mars Hill, he charged that they spent

their time "in nothing else but to tell or to hear some new thing." Consistency and continuity in educational labors require beliefs more firmly fixed than those which last only till something new is put forth. Sharp distinctions must be made, too, between principles to be put into practice, and the processes employed for doing this. Each succeeding generation of teachers must learn anew all these things.

Out of unrest and change progress may come, but no progress is possible in teaching or elsewhere where the teaching procedure found best through experience does not abide. In the sciences change in the theories held, and in relative values of facts taught, is ever occurring. New teaching outfits replace the older and less serviceable ones. On the other hand the science teacher even as other teachers is profited by taking into account educational constants, and in due time as a result of personal experiences he, too, should become able to formulate statements beginning, "Educationally, I believe," etc.

Among many such possible statements the authors venture to suggest by way of illustration some believed by them to be fundamental in elementary science teaching, and which very properly should shape its entire purpose and procedure:

(1) To acquire an education, or to become educated, *involves a desire for knowledge* which dominates an individual throughout life. Its ends are not attained

at graduation from school. To aid pupils in getting an education is to awaken in them this desire, and so to direct it, nourish and stimulate it, that it becomes a dominant force in life.

Teaching as a process implies not only that some one give instruction but as well *that some one wants to be taught*. It is a mutual matter, mind acting upon mind. Action and reaction if not equal are at least in evidence. Upon the teachableness of the learner, his willingness to actively respond, hinges very largely the success of the teacher. To go through the forms of teaching yields no satisfactory results when those under instruction have no desire to learn.

This does not mean that the science teacher whose pupils are to make satisfactory educational progress under his tuition must sugar-coat and predigest what is presented to them. On the other hand, he must avoid such choices of matter and of method as will result in their dislike or dread of the subject. No really fundamental topic in the elementary phases of science subjects needs to be omitted in so doing. There will be need at all times of a large measure of teaching ingenuity and skill on the part of an instructor. Progress at first may be slow, but only as necessary to keep pace with the abilities of the pupils to master the difficulties of each succeeding topic. Large account should be made of the fact that in normal human lives the greatest measure of satisfaction, and the largest degree of happiness, *centers in achieving what*

is thought to be worth while. The crowning glory of it all is the consciousness of possessing the power to achieve. That which has been done may not have been easy, but the doing of it fits one to do what is yet more difficult. Fitness for yet greater tasks is the abundant reward of well doing. It is to be remembered, however, that what is set as a task for pupils to do *must appeal to them as something worth doing.* Herein is a word of warning to the science teacher if he would arouse and foster a desire for knowledge in his pupils. And herein, also, is an opportunity for influencing the judgment of pupils concerning what is most worth while.

(2) The school is a place *for learning how to satisfy this desire for knowledge.* The school could not furnish if it would the varied conditions that come to people in later life, nor the complete round of knowledge required in living. It cannot teach what should be done in all specific cases that may arise in the affairs of men. The problems of school life, its system and outlook, are necessarily more or less unlike those of home life, of business, of the industries and the professions. While much valuable information of an elementary sort can be imparted in schools, far more important than the value of this information itself is the training which can be given pupils for skill in discerning clearly the conditions which enter into any problem confronting them and requiring solution, and in going at its solution successfully. It is a training

for general capability and competency, and it finds its best expression later in any of the varied walks of life. The teacher and textbooks are not available when school days are over. But a training may be had in school, especially in connection with the study of the sciences, which enables one better to assemble the facts that have any bearing upon each life interest as it presents itself; that recognizes the relative importance of these facts and their relationships to one another. This should enable one to arrive at beliefs so definite as to feel reasonably well assured of success when application is made of them as working hypotheses. The school, then, may not only be a place to satisfy immediate desires for knowledge, but through its training there may be given in varying degree to those who would avail themselves of it an intellectual skill and readiness which will meet all the ordinary demands of life.

The teaching problem, then, becomes one of training pupils to be students. Disciplinary measures can be enforced, laboratory and examination papers can be reviewed and graded, but to bring about in the lives of others an habitual attitude and practice such as characterizes the student, and to do it largely without consciousness on the part of a pupil of the purposes of a teacher, requires a continuity of effort that is rare. It involves an ability to control the mental activities of others not always possessed by those desirous of

teaching science, even when sufficiently well versed in the subjects they desire to teach. However, a clear understanding of the problem is necessarily involved in preparing boys and girls to be life-long students, and masters of the ways of acquiring knowledge. It makes the teaching problem no more difficult, and is preliminary to any solution of it. What it is to study (p. 97) is discussed in a later chapter.

The immediate ends of laboratory and classroom work in the sciences of secondary schools is an understanding of the phenomena, the theories, and the practical applications of the branch studied. But the ultimate end of its teaching procedure, *exceeding in educational worth all the information gained in the course,* is ability to satisfy one's desire for knowledge, and a self-confidence that one will know better how to proceed in mastering situations in life into which he may come.

(3) The science teaching of the secondary school may be so conducted as to develop the initiative in an individual—the habit of ascertaining what should be done, *and undertaking to do it without being told.* This, too, should be a by-product of science courses, and is more valuable than any ability to pass examinations or to attain high standings in class work. A confidence in one's ability when born of achievement is fundamental in educational processes. Science teachers need to subscribe to the belief that secondary school

courses can be so shaped as to build up gradually in the high school pupil, slowly it may be but nevertheless surely, *a consciousness of ability to do.*

A desire for knowledge that dominates one's life, a training in the ways of mastering human learning, and a feeling of power within one's self so to use knowledge as to control the affairs of life, are fundamentals in that intellectual development of man which is called education. There is no age nor time during life when it needs to cease.

A somewhat philosophic view of the relationship of secondary school science to life affairs, and to society in general, notes that in the teaching of the elementary stages of science even as in the normal affairs of human life there is necessary:

(1) A noting and grouping of existing conditions. This involves *observations of the facts* of any situation, and *inferences as to the significance and relationships of these facts.*

(2) A formulation of a plan of action *based on facts observed and inferred.* This constitutes the working hypothesis of any course to be pursued.

(3) Attempts to achieve desired results. This may involve repeated modifications of the original plan of procedure, and the testing out of any working hypothesis in its applications.

To a beginner in science studies starting points for sustained constructive thinking are found in various

personal experiences. What is known through experience is concrete. On the other hand, whatever is unfamiliar or not well understood may be considered educationally abstract. Thinking to desired ends is unlikely when it does not originate in what is more or less well known, and when the attention is not concentrated rather than distracted. To challenge the attention of any learner, to arrest and hold it, *often requires a repetition of his past experiences* in some new aspects, or in a somewhat more complex form.

Class instruction may consist very largely in repeated regroupings of former knowledge in connection with some few new facts. About something well understood as a center are clustered life's personal experiences, and any other information suitably related to the central fact. The applications, too, of what has been learned must be in the realm of the "known."

In the secondary school sciences such aims as the above may well constitute a dominating purpose of the teaching process. This differentiates the work sharply from college science where the aim is likely to be mastery of any subject *as science*. With college students there is supposed to be sufficient intellectual development to comprehend facts largely foreign to personal experiences. The theoretical in knowledge is presented to them as students more or less deductively. The college professor of any science is more concerned over a presentation of his subject to his students *in a scientific way* than with keeping them "interested" in

it, or with so shaping his requirements as to establish studious habits. It is a more advanced stage of science instruction given to more mature people, and certain preparations and fitness for this work may safely be presupposed. The formal lecture of the college classroom, and deductive reasoning concerning the theoretical and mathematical in science, are both out of place with high school boys and girls, however fluent and well-prepared in these respects the science teacher as a recent college graduate may be. Inductive teaching as a characteristic of the initial stages of every new topic taken up in a high school science adds fact to fact, and relationship to relationship, resulting in the formation of more and more complex groupings as the mastery of a science in its elementary stages proceeds. More rapid progress becomes in time, however, both desirable and possible, and in the secondary school the substitution of deductive for inductive procedure should become marked towards the conclusion of any science course. Deductive science teaching in high schools may very suitably be characterized as *informational,* and inductive teaching as *inspirational.*

Summary

1. Educational principles, and educational philosophy, for beginners in teaching. Distinctions between principles and processes in teaching.
2. Educational constants.
   (a) Desire to know. (To educate is to arouse, direct,

and stimulate this desire. Teaching implies a learner as well as an instructor.)

Subject matter and teaching procedure to be avoided.

Chief incentives to life efforts. Character of tasks assigned pupils.

(b) Mastery of ways for satisfying a desire for knowledge.

Training in solution of "problems" to fit for mastery of life situations.

Making students out of pupils. Difficulties involved, and the advantages from a clear understanding of them.

The immediate and primary purpose of school instruction.

(c) Initiative in school life and in out-of-school life.

Self-confidence based on achievement as a factor in life's successes.

3. Relationship to life affairs of secondary school science *as training* rather than instruction only.
4. Nature of class instruction. Where class thinking begins and ends.
5. Relationship of inductive and deductive teaching processes.

CHAPTER IX

EXAMINATIONS IN SCIENCE TEACHING AS TESTS OF PROGRESS AND PROFICIENCY

(A) Mental Tests in General

With the various mental tests employed for promotion of pupils in the administration of public schools science teachers as such have little immediate concern. The science subjects are distributed more with reference to one another than to other subjects taken in the same grade. The classes which come to a science instructor have in general had their fitness determined otherwise than by abilities of individual pupils to take the particular science subject of the grade to which they have been assigned. Grading throughout the elementary schools, and very largely in secondary schools, is and must remain a horizontal stratification. It is not determined by completion of the units *in series* of any of the fields of education such as science, history, and mathematics. Because of these conditions the science teacher takes pupils whose ability in reading, writing, spelling, and calculations puts them fairly abreast of one another, and whose stages of progress in history, English, and language are fairly equal. For

instructional ends in general these groupings serve their purposes well enough, and may be as good as any for the science teacher. Further adjustments occur by reason of "science electives" whereby in many schools pupils for one reason or another, and perchance for no good reason at all, choose more or less advisedly which of certain science subjects shall be pursued. Of necessity such conditions as have been noted ignore completely any and all native ability in pupils for science studies, and any previous acquaintanceship with natural phenomena in both the physical and biological fields.

The science teacher from the beginning of every course seeks to adapt his teachings to pupils under instruction insofar as this can be done, rather than attempt to make them conform rigidly to "standardized" procedures in choices of subject matter, and in its manner of presentation. Especially is this the case in elementary science courses. So, in order to get a suitable understanding of his particular "teaching problem," very early in the course and even at its outset use can profitably be made of a "Range of Information Test" [1] covering possibly the whole field of elementary science, or any particular portion of it as desired. These tests can be prepared by an instructor himself, taking into account his teaching experiences and his knowledge of conditions to which his teaching must conform; or, purchase and use of standardized tests may profitably

[1] See Appendix C.

be employed. A basic list of terms such as given in Appendix C may be used either as a whole, or it may be taken at different times in parts either by subjects or otherwise. Some suggestions promotive of efficiency in their use are noted in connection with the list given. Substitutions of terms in the list may be made at any time as desired. At all times it is to be kept in mind that the chief end in view is to ascertain into what sort of background of science knowledge the instruction to be given must be fitted, both for the class as a whole and for its individual members. Coming early in the course as such tests should, there is much in the way of enlightenment in their results for both teacher and pupils. To the pupil it is a survey of the field of instruction into which he is to enter while as yet no responsibilities by reason of laxity in efforts may be charged up against him. It provides somewhat of a notion of the effort to be required of him even from the very first of the course. To the instructor information is furnished concerning which of his pupils are likely to need special helpfulness and consideration, and of which pupils much should be demanded from the beginning of the course.

(B) Examinations for Proficiency

Elsewhere (p. 116) brief mention is made of purposes of examinations in the general scheme of school instruction. Science teachers even as instructors in other fields of education must employ examinations,

written quizzes, and various tests, *but always as means to an end* and not as ends in themselves. Certain characteristics of examination lists, and some precautions to be observed in examinations, may be discussed here to advantage. As a basis for grades and promotions no teacher can with security to himself discard examinations, nor substitute therefor personal estimates of fitness. Neither can an instructor be fully assured that the relative merits of work done by pupils under his instruction are evaluated with justice to all in absence of some suitable written class tests. A succession of tests as progress is made in a course marks off stages of advancement which in the eyes of pupils is quite a matter of importance.

That the integrity of examination results may be maintained, and that pupils of honest intent be not penalized for their honesty, precautions must be taken at examination times of such nature that as a matter of course cheating is unlikely. Such precautions may require small classes, or subdivisions of classes with vacant seats separating pupils, but no large amount of administrative ability or added labor for the instructor is necessarily involved. No pains is too great to avoid impeaching the integrity of examination results, and lowering the standards of honesty in all things. Where any act is considered "all right if you can get away with it," and in school life this is applicable to grades and promotions no matter how attained, there need be no wonderment over lawlessness on the

part of generations trained to ignore the nice distinctions between things right and things wrong. On every hand are to be noted risks taken with expectation of not being caught, and these not only in financial transactions but as well in social and civic relationships generally. That there be in evidence any system of espionage, or any prominence given to preparations of any sort to "catch" cases of dishonesty, is in itself prima facie evidence of poor psychology on the part of a teacher, and of a serious lack of knowledge of human nature. Better eliminate examinations than make them a means for training in deception and dishonesty, and the occasion of loss of confidence on the part of pupils in their fellows. This is of course no more true for science teachers than for others.

As previously suggested the teacher of science subjects is likely to be free very largely of the Intelligence Tests so much in evidence in school work to-day. But Achievement Tests [2] as outgrowths of the instructor's own experiences, or employed as standardized tests, aid science teachers in maintaining year after year some degree of uniformity of teaching results with successive classes. Coming as these tests do at the conclusion of a topic, or of some division of a subject, their instructional values may be small. In nature they are much the same as semester "finals," but to them at-

[2] For Ruch-Popenoe General Science Tests (Forms A and B): World Book Co., Yonkers-on-Hudson, N. Y. For Glenn-Welton Standardized Achievement Tests in Chemistry: Earl R. Glenn, 425 W. 123rd St., New York City.

taches none of the risks of failure or success which too often taint with a gambler's risk the "final exams" of high schools even as in colleges. For the teacher these results have much that is enlightening concerning teaching values attained, and much which provokes to efforts for better teaching.

(C) Some Suggestions

Suggestions of details pertaining to examinations, as well as some general principles to be followed in connection with holding examinations, are permissible here as an aid to teachers who are lacking in experience. In time instructors modify procedures to suit their own experiences and preferences. What is outlined is by way of suggestion only:

I. Plan to have examinations upon the completion of every major division of a subject. Let the question list be restricted to such section. Averages of the results of these examinations can be used as a basis for grades of pupils. "Final examinations" thus become unnecessary save for those pupils whose ranking is otherwise a matter of uncertainty.

Where a pupil is reported "Failed," there is ever the possibility that the teacher's grading may be challenged by the pupil or by his parents. In such cases it may be wise to have recourse to an examination covering the entire semester's course. This list of questions always fair but searching may be of the teacher's

own selection. Under some circumstances, it may be better to use some standardized achievement test. From an instructional standpoint there is little value in any such test, and the results may in nowise change opinions previously held. In other respects it is a matter of much importance in its bearing upon the professional standing of a teacher.

II. Question lists should include in ever-varying proportions such requirements as:

(a) Questions testing memorization of what has been taught in class and of what has been study in textbook of the meaning of which there could have been no misunderstanding.

(b) Questions which test ability to make applications of what has been taught, but teachings now presented in some new relationship preferably more or less familiar in life affairs.

(c) Some one question at least, possibly one out of eleven questions where but ten must be answered, pertinent and fair but likely to be beyond the ability of the less capable pupils of the class, illustrative of the fact that all has not yet been learned about the subject.

(d) Some problems which are not involved or especially difficult, and questions calling for numerical answers of importance.

(e) Description of some simple experiment, original or otherwise, illustrative of some teaching given. De-

scription or diagram of simple apparatus used or discussed.

(f) Write-up of observations for some brief demonstration experiment performed before the class by the instructor, with a full explanation of what was observed.

III. In framing questions to be asked keep in mind what are possible answers for every one of them. Seek to make the questions so clear and definite that but one correct answer in general is possible. Avoid use of language which may not be understood fully. Plan requirements so that grades of better students are likely to range 80-95 per cent. Then have question lists written out in advance, possibly on a portable slated-cloth blackboard; or, what is far better, hand out sheets of duplicate examination lists. Thought questions rather than memory tests discourage "cramming," and lessen likelihood of cheating.

Special care should be taken where questions are put upon the blackboard that no pupil shall be handicapped or penalized by inability to see and easily read every requirement.

IV. Insist that papers handed in be legibly written whether in ink or pencil, and be in small-size well-formed letters, with least reasonable amount of paper used. Brevity in answering without sacrifice of definiteness and completeness is preferable to "much speaking." Have name (and file number) on every sheet

handed in. (Oftentimes by writing on both sides, one sheet only need be handed in.)

V. Arrange seating so that likelihood (temptation) to copy, or to give or get aid, is eliminated so far as possible. Do not put conscientious pupils at a disadvantage by toleration even of appearances of evil. Encourage honesty of purpose and spirit of fairness by being as a teacher ever fair and considerate. In all respects appear to take it for granted that every one is honest. So make arrangements that no issue is likely to arise between a pupil and the teacher from any questioning of motives.

VI. In marking examination papers:

(a) Careless or indifferent markings are intolerable. To the pupil these tests are of importance.

(b) Upon each answer place the valuation given it as a separate answer. The sum of these values, divided by the total value had all answers been correct, gives a grade intelligible to the pupil.

(c) Get the graded papers back to the pupils without any considerable delay. Let this be before answers become matters of indifference to pupils, and before opportunity passes for instruction concerning matters of misapprehension or lack of understanding on the part of the class as a whole. In cases of manifest error in marking, make changes in grade so that no injustice may be done any pupil. Where in general the class as a whole fails in an examination it furnishes

occasion for an instructor to take heed to his own ways. Wide and unexpected differences in grades of pupils should occasion persistent but kindly inquiries as to causes of failure by any pupil.

VII. The general purpose of the written quiz should never be lost sight of. It is a time of taking inventory of existing conditions, and "taking stock" of assets and liabilities, both for teacher and pupils. Efficiency in instructional processes in every way is promoted and perfected by use of examinations.

VIII. In addition to their value for the teacher as tests of achievement by pupils, and as a check upon the efficiency of his teaching, these written tests have value in themselves. They furnish:

(a) Opportunities to pupils to recall certain essentials of the topics under consideration, and thus fix these essentials in memory by reason of the repetitions required.

(b) Proper notions of worth to pupils as to what are the essentials of that part of the subject. This assumes of course that the teacher is so well trained that he selects important parts for consideration in examination. Pupils soon learn whether or not they themselves have selected essentials when preparing for an examination.

(c) Opportunity to make applications of what supposedly has been learned. The ability to do this is one of the most desirable products of science study. It can be gained as a result of frequent opportunities

to apply the known in new situations, and such opportunities are afforded by the science examinations.

Summary

1. Basis on which science pupils are assigned to classes. Lack of testings of fitness and capacity for taking any science subject. "Range of Information Tests" for guidance of instructor.
2. Examinations as measures of proficiency. Their relation to personal estimates of pupils.
   (a) Precautions to assure honesty in examination results. Attitude of instructor in connection with examinations.
   (b) Use of "Achievement Tests" for maintenance of teaching standards. Distinction from semester "finals."
3. Detailed suggestions as to:
   (a) Times for examinations, and need for "finals." Course of an instructor when a report of "Failed" for any pupil is challenged.
   (b) Character of questions in general with regard to: (1) memory tests; (2) applications of teachings given; (3) questions especially difficult; (4) problems; (5) descriptions of some experiments with some specified teachings; (6) write-up of an experiment performed during the examination hour.
   (c) Phrasing of questions. Provisions made so that pupils experience least difficulties in seeing questions.
   (d) Requirements as to form of papers, and character of work handed in.
   (e) Marking and grading of papers.
4. Educational values of tests.

CHAPTER X

WHAT IT IS TO STUDY IN HIGH SCHOOL SCIENCES

School attendance implies study. Not least of the efforts of science teachers in secondary schools is so to shape their requirements, and carry on their work day by day, that the chief product of their labors shall be an acquired ability on the part of their pupils to apply themselves *as students* to any and all of life's problems.

Organized school systems despite their perfection and all their outlays really count for little educationally when teachers through whom as individuals the supposed advantages of schools are to accrue to pupils have neither a vision of purposes nor a concern for possibilities in school training; when they remain blindly indifferent concerning sustained efforts for growth of pupils in ability to think.

For the sake of perspective it is well at times to consider how the problems peculiar to the schoolroom appear when viewed from without, and in relation to life affairs as a whole. How shall the purposes, the procedure, and the accomplishments of the science teacher have any bearing on the ability of one who later in life as a business or professional man, farmer, or home-

maker must study and solve the "problems" of life? What is it to establish through the work of classroom and laboratory that attitude of a student, and that activity in studious practices, directly affecting the procedure of a lawyer as he studies the case of any client?

In the latter instance from the client himself, and from all other available sources of information—witnesses, personal investigations, books of law, court decisions, community interests—a lawyer seeks first to get all "facts" bearing upon the case. As these facts are being accumulated *their various relationships are noted.* Those facts not vital to the case at issue are ignored. Where necessary information is lacking, further efforts are made to acquire it. Full consideration of the facts and their significance makes possible a "working hypothesis" *which is of the nature of a conclusion as to what is best to do under the circumstances.* Then follows the *application* or trial of this plan in court before judge or jury. It not infrequently happens in these trials that evidence heretofore unknown is introduced rendering necessary an entire remaking of the plan of presentation previously settled upon. It is as when a scientist learns of facts, newly discovered it may be, affecting theories before entertained and taught by him, *and the facts are not in accord with the theories.* So soon as it is definitely established just what this new information is, and what bearing it has on the theories held, *the theories must be recast.* Where opinions, beliefs, or plans do not accord with

facts, the facts prevail. And it is a distinguishing characteristic of a student, as it is of a scientist, to possess the ability to review and regroup all significant facts in any case, and to reach new conclusions which when application is made of them shall accord with the facts.

The trained mind is superior to the material by means of which it acquired its training. To be able to group and organize the facts gained from experience and experiment, from the statements of text and reference books, and from teachers and other people, involves study training. Though always best attained, perhaps, as incidental to the routine of the usual school procedure, its attainment need be neither haphazard nor problematical. On the other hand, it can scarcely be expected to be other than variable in degree with different pupils even when they are held to the same requirements. Possibly in many cases there may be little progress apparent. Some pupils will develop studious ways under unfavorable teaching conditions, learning how to study unaided by schools and in spite of schools. Any training in schools to make students out of pupils demands of teachers a clear understanding of what it means to study, and a procedure both consistent and persistent. Science subjects may be so presented that topic by topic they are of the nature of a series of "problems" the chief end of which is not so much a mastery of the facts in the case as it is the establishment of habits of effective study—not so much

grades and graduation as it is pupils *who know how to study, and who habitually have the attitude of students* in any of the affairs of life. Classrooms and laboratories are study rooms. In this conception of teaching the out-of-school experiences of pupils are fundamental both in the initiation and in the conclusion of school studies.

To the physician every patient presents a "problem" the solution for which lies largely in a correct diagnosis of the case. This involves both extended observation and correct inferences. In the treatment prescribed there must ever be the need to take notice if it fits the needs of the patient, thus involving it may be a possible review of the facts of the case and a more extended knowledge of it, together with the formulation of a supplemental diagnosis with its consequent changes in treatment. The successful business man in his extended operations must take exact account of all the "facts" bearing upon his enterprises, and what these facts signify in relation to the various problems that come before him demanding wise action and the fewest possible mistakes in business. The efficient housewife as a successful household administrator must be competent in reaching and when necessary of reviewing decisions which on the one hand are based upon facts affecting the affairs of the household, and which upon the other constitute the working plans upon the successful execution of which the welfare of family life depends. Upon the variable facts of weather and

soil conditions, the farmer must be able to base decisions that will "work out" when application is made of them. He, too, must be competent to revise his plans in accord with changing conditions, and make his procedure fit the conditions.

Indeed, in all these aspects of life and the various others of which these are but types, are to be seen in varying degree and varied form the procedure and the attitude of the scientist in his labors and his investigations. The "scientific attitude" and the "scientific procedure" are not only fundamental to advances in human knowledge, but they constitute the mental states and working processes natural to effective service in all the walks of life. The ways of study in schools should be wisely ordered *first steps* in becoming competent students in life's affairs. Study in school is in its adaptations and uses of subject matter but a more or less varied round of perfecting one's self in a routine characteristically scientific.

This presupposes, then, a procedure in the science teaching of secondary schools which constitutes a training whose chief product is students. It seeks the formation of those "habits of study" which find their perfection in the later and continued out-of-school studies. The purpose in such a training scheme of manuals and texts and reference books, of the classroom and the teacher, are discussed in the chapters devoted to those topics. It is unlikely in this connection that too much emphasis will be placed on the need of

clear conceptions on the part of the teacher that the study habit, and those mental habits conducive to study, *are gained through use of the subject matter of the sciences,* and not as abstractions from it. Success in this as in other teaching efforts is likely to come in largest measure as a result of wise planning and persistent efforts.

One of the best methods of acquiring a clear notion of what it is to really study is to analyze the action of one who is a successful investigator in any field of scientific effort. Not infrequently is it true that such men may at times utterly neglect the need for food and rest through long periods of time so intent do they become in accomplishing what they have undertaken as a "problem" to be solved. Anyone who would be a student must be in earnest in whatever is undertaken, concentrating all his energies upon the task at hand whether laboratory work, text or reference book work, or any other activity in the learning process.

Another point to note in the conduct of the research worker in science is his almost uncanny keenness of discriminating concerning the things within the field of science which are of primary importance. He has a well-developed ability for picking out whatever in any problem relating to scientific aspects of life is of primary importance, and of ignoring insignificant facts and whatever is not essential. A beginner in science courses cannot be expected to start out in his new

work with any such capabilities. Here are opportunities for teachers to render services which are more of the nature of training than of instruction. No inconsiderable part of the plans and purposes of science teachers should be in this field of effort. Not only in class time by giving it formal attention, but as well in periods of laboratory work and of supervised study, pupils are to be exercised in gathering information and in making relationships of facts, and in intelligent discrimination as to the relative importance of these facts to the problem under consideration.

College students preparing to be teachers are supposedly able to analyze the teaching procedure of their instructors in a subjective way, and to profit greatly as prospective teachers from objective presentations of science teachings. High school pupils as a rule cannot be expected to do this, and formal training is needed that they may become capable students, knowing how to study and how to do it most profitably.

The rate of accomplishment as it measures the study power of students who are in earnest, and who know how to make choices of the essentials in thought material, is so markedly in contrast to what is done by those who have never learned how to study that it is well to point out these differences to high school pupils, emphasizing especially the folly of their taking so much time to accomplish so little. Attempts to improve methods of study may at times be urged on the

ground that the better students frequently have more time for other things due to the economy of time which goes with correct habits of study.

Another trait of the successful student is an almost intuitive grasp of the relationships of things. He does not waste time trying to memorize disconnected data. He appears to learn and seems to retain information with but little conscious effort not only because he is interested in what he is doing, but because he makes associations of the right ideas as he proceeds. Relationships between newly acquired thought material, as well as between what is new and what had been previously learned, are quickly noted and firmly established in mind. There is thus built up a body of knowledge which is usable because the bearing of each part of it upon every other part is comprehended. The student, as well as any one in the daily walks of life who has acquired habits of study such as these, will not lack initiative. As a rule, he notes quickly what should be done on any occasion, selects from his well-ordered store of knowledge that which applies to the case in hand, and confidently applies his knowledge to the accomplishment of his aims and purposes.

Since necessarily much in the way of moral instruction devolves upon the teacher, it is well at times to point out to pupils *that only by use of their natural abilities to their fullest extent* are the requirements of their moral natures satisfied. Of those who are brighter more is demanded. Their mental equipment is part of

a natural endowment in the make-up of individuals. Its most complete development is a duty naturally devolving upon an individual. He who fails to make the most of his abilities, mental as well as otherwise, fails in obligations to himself and to others. His course is wrong rather than right. Of everyone is demanded the best of which he is capable, and no more is demanded of any one than he is able to do.

Summary

1. What school attendance implies.
2. Relation of "study" in school to the study made by a lawyer of the case of a client.
   - (a) Acquisition of all facts bearing upon the problem.
   - (b) Discrimination in the relative importance of these facts, and establishment of relationships among them.
   - (c) Conclusions reached as an "opinion," "belief," or "working hypothesis."
   - (d) Application made of this opinion formulated as a course of action.
     - (1) Modification when the hypothesis as formulated does not accord with the facts of the case.
     - (2) Distinguishing characteristics of a scientific procedure.
3. Study-training not to be haphazard but incidental. Its procedure well-defined, and consistent. Results with different pupils.
4. Use of "problems" in science as study training. Laboratories as study rooms.

5. Study of his "cases" by the physician.
6. The business man, housewife, farmer, and others as students. "Scientific attitude" and "scientific procedure."
7. Characteristics of study training in schools.
   "Habits of study" in connection with subject matter.

CHAPTER XI

THE TEACHING "CYCLE" IN SECONDARY SCHOOL SCIENCES

In theory teachers of secondary school science must be left largely free in making choices of subject matter, and in ways of presenting it. This is necessary in order that the teacher may adapt his work to teaching conditions. It presumes a resourceful and qualified teacher who has sufficient time and initiative to adapt means at hand to ends sought. Very commonly, however, science teachers are likely to follow the presentation of some text or manual, despite the fact that a too strict adherence to the requirements of one or the other is fatal to the best teaching. On the other hand, any go-as-you-please procedure, with no two science teachers following the same plan in the same subject, is inconsistent with claims made in behalf of the sciences. Save in case of a few master teachers such lack of systematic procedure inevitably involves educational waste.

So far as organization of knowledge is concerned, it can be assumed that the mental activities of high school pupils are in the main illogical and non-scientific. Teaching efficiency requires of an instructor and of his pupils a teaching round, or "cycle," which is

pedagogical rather than scientific, and which is not necessarily in accord with scientific classifications of the subject matter under consideration. Primarily it is children who are to be taught rather than any science. In its elementary stages the subject matter of the sciences *should be presented according to the needs of those under instruction.* Classification of knowledge in accordance with the theories of science is of a later stage, though the procedure in acquiring facts and in interpreting them must ever be scientific from the outset.

The larger needs of pupils, those which are to dominate the teaching situation in any science subject, may be summarized for our purposes here as follows:

(1) Arousing of interest, and stimulation and guidance of a desire to know what is to be presented.

(2) Growth in the belief of pupils that what is being taught them is quite worth while.

(3) Marshaling by the teacher of the concrete[1] things of the life experiences of pupils in the particular field of science being studied, together with whatever has been learned from wisely chosen experimental exercises in school.

(4) A presentation of the theoretical side of the science in order that the grouping of facts learned may go on in accordance with such theories.

Courses in Nature Study and in General Science con-

[1] Educationally only that which is understood is concrete. It includes the vast fund of knowledge learned by experience.

tribute to the teaching of secondary school sciences insofar as they train the pupils in methods of observation and inference. Within narrow limits there should be established by such courses attitudes of mind and manner of thought directly serviceable in all later studies of the differentiated high school sciences. There should be carried over from these elementary courses to this later work the use of introductory discussions in connection with the more important new topics. These discussions may be made to center in questions pertaining to the topic of the hour. They should involve many facts with which the pupils are acquainted by reason of their life experiences. This knowledge of life affairs and of life interests, though lacking in organization and in an understanding of its full significance, is an asset of largest educational worth in quickly securing from the pupils an alert responsive mental attitude, and in making available for immediate use a large fund of information capable of being organized in accordance with scientific procedure.

The fact that sounds of blows of a hammer as watched from a distance, and the whistling of a distant locomotive, are not heard till some time after the occasion for the sound has been noted by sight may be a common-place in the experience of childhood. No inquiry may ever have been provoked as to causes of these delays in hearing. But in teaching the nature of sound, its velocity, etc., this previously acquired information becomes at once of greatest worth in shap-

ing problems for the purpose of directing thought effort, and for use in the verification of general teachings regarding sound. Simple experiments performed by an instructor in connection with any questions asked may when suitably chosen not only introduce new knowledge to pupils, but serve as centers for instruction about which to group what is already known in relationships characteristically scientific. Both experiments and questions, whether wholly original or used from some manual, keep in the hands of an instructor the necessary control and guidance of discussions whereby desired teaching ends are best attained.

However much or however little of time and originality high school science teachers in general may have, any laboratory manual should render a real service to the many teachers who do need assistance by providing a well-digested list of questions based upon life experiences assumed to be common to the pupils taking the course. This question list may be complete in itself, or it may be merely suggestive of a complete series. It may include, or it may only suggest, experiments to be performed by the teacher the purpose of which shall be (1) to give significance to the new matter upon which instruction is to be given; (2) to stimulate and sustain a mental attitude receptive of instruction; (3) to furnish centers about which to group instruction; (4) to make clear the scientific relationships and procedure in experimental work, and in its interpretation.

All this leaves the teacher free to adapt or to originate requirements necessary for special or unusual teaching conditions. Both the questions and the experiments seek first of all a mental condition—a "class-mind"—which shall furnish to a well-prepared instructor the opportunity prerequisite to the most effective sort of teaching.

And it is at this stage of teaching that carefully selected reference readings may be used by pupils to excellent purpose for the enrichment of the course, and for giving it a desired flexibility. It is an excellent plan where funds permit, to have several copies each of carefully chosen reference books upon every science subject taught at all times available in the science rooms. These should be texts other than the book adopted for regular use. A different viewpoint, or a different way of presenting a given topic, may thus be gained. Sometimes things that are difficult to grasp are taught in a masterly way by a particular author whose book on the whole may not be well suited for use as a regular text. If a half dozen copies of such a book can be obtained and kept at hand, pupils may be referred to certain sections of it at the proper time to good advantage. A supply of such supplementary texts oftentimes may be had through dealers in second-hand books. Again, the textbook in regular use—say in chemistry—may devote relatively little space to descriptive matter, dwelling more largely on fundamental principles and theory. In such cases copies of a good

college text for the more capable pupils may be desirable. Even a limited use of these books keeps pupils profitably occupied when ahead of their classmates.

If at first definite assistance be given pupils in the selection of suitable reference books, and in the use of index and table of contents, they develop ability to select and use reference books for themselves to good purpose. *Through such training they become skilled in the art of study.* Reprints of original papers on epoch-making discoveries are very valuable reference books. Through their use can be interwoven some of the historical aspects of the science. It is seldom that one finds in a modern high school text so clear-cut an exposition of the important theories of science as was originally given by the author of the theory. Avogadro's Hypothesis, as an example, was better expressed by Avogadro himself than by later authors. The setting, too, of the great discoveries, and the formulation of hypotheses based upon them, is often best given in the original papers.[2] Use in connection with these references of any foreign language of which pupils may have a reading knowledge is to be encouraged since it gives valuable correlation of science and language studies. Oftentimes reports on references very properly may be required of the more ambitious in the class, and of those who as naturally rapid workers are

[2] Such series as the *Alembic Club Reprints* and, in the French, *Les Classiques de la Science* (Librairie Armand Colin: Paris) are invaluable.

likely to have spare time in the laboratory hour. Fortunately there are on the publishers' lists not a few suitable books which present many phases of scientific achievement in a sufficiently complete and accurate form, and with a style and a freedom from technical terms to make them attractive to high school pupils.[3] One or two such books *as part of the laboratory equipment* are preferable to a library full of books which lack in attractiveness for boys and girls.

In all secondary school sciences laboratory manuals of a high grade of excellence are already on the market either to accompany some special text, or for use with any text. In these manuals the discriminating science teacher can find desirable sets of experiments *for use by the pupils.* Quite uniformly the facts which these experiments bring to the attention of the pupils, the discrimination required as to the relative worth of these facts, and the scientific relationships readily discerned among them, leaves very little to be desired.

Probably there is no substitute for the requirement that the results of laboratory exercises such as observations, inferences, drawings, mathematical calculations, etc., be written out and handed in for correction and credit, or for inspection at the pupil's desk by the instructor. The pedagogical value of this written work as discussed elsewhere (pp. 27–34) involves on the pupil's part concise statements of his thought relationships. His attention at these times is called to whatever he

[3] Such as *Creative Chemistry:* Slosson. (Century Co.)

lacks in comprehension of the subject matter discussed. The free use of texts and other books as sources of information *when a need for information has become painfully apparent to pupils in writing their laboratory papers* furnishes conditions quite ideal for a study hour. It is favorable in the highest degree for training pupils to be students in the true sense of that term. Like the "Sieur Brun," who according to Jean Rey,[4] was filled "with astonishment, *and with a desire to know* whence the surplus weight had come," pupils will frequently encounter something in their laboratory work to really interest them, arousing this desire to know. These are times when educationally it is well to "strike while the iron is hot." Through the use of books in this way as sources of information and as means of enlightenment, in due time there is acquired an ability to find desired information expeditiously and unerringly so far as library facilities at hand permit.

It is believed, too, that certain question lists should be a feature of laboratory manuals even as we are accustomed to the exercises found generally in science texts. Their differentiation from questions used to introduce studies of a topic, and from the questions in the text, *are matters of teaching purpose* rather than of form and content. In these lists there should be (1) some leading questions to suggest what are the purposes of various experiments, and at certain points

[4] Essay (1630) on "Increase in Weight of Tin and Lead when Calcined." (See "Alembic Club" Reprint.)

of any experiment why a certain procedure is followed; (2) a review of some of the more important facts of the laboratory exercises and of the introductory discussions, especially such as are likely to enter into the constructive thinking demanded in the next succeeding teaching assignments; (3) certain thought-provoking requirements of the nature of "problems" in order to sustain and direct interest, and to promote a spirit of inquiry; (4) a demand for enough use of the text so that its content as taken up topic by topic becomes somewhat familiar, thus anticipating and making easier the later task of mastering the text matter as a whole.

With the use of a text later by pupils during the write-up of laboratory exercises, and again as a source of the information required by the question lists, the purpose of any further assignments of lessons in the text will then be narrowed (1) to the rounding out and completion of discussions of each topic in turn; (2) to furnishing material for a quiz for which pupils are required to master everything which the book gives upon any topic as a whole, or upon certain selected portions of it. Teaching experience warrants the use of text matter as an effective means of exerting pressure upon pupils for that sustained effort which is involved in the forced mental activities of school days. Ability to repeat words and interpret book statements must ever remain a ready means with successive generations of youth for gauging the preparation of lessons.

In this teaching cycle there remains only to mention that necessary evil the formal written "examination," for which there is no satisfactory substitute (1) as a basis for grades and for promotions in school life; (2) as a suitable stimulus to which the teacher from time to time may resort as pupils weary and relax in reasonable degrees of effort in their school tasks. To approximate a certain irreducible minimum of the evils of examination, and a maximum of their teaching values when used as the last of the teaching stages of any topic or series of topics, involves certain precautions and purposes (pp. 86-96), but no "problem" of major importance.

In connection with a summary of these teaching stages it is to be remarked that while distinct purposes are assigned to each such stage, any unchanging adherence to their order in teaching procedure, and any uniformity of emphasis placed upon these several stages, will destroy the spirit and defeat the purpose of their differentiation. The different topics of all secondary school sciences require a varied treatment for the sake of variety itself, and for a maximum of teaching value. But this in nowise lessens a demand for that teaching efficiency which is best attained through judicious use of some such procedure as set forth in "A Cycle of Science Teaching" which follows. It enables an instructor at all times to be conscious of the immediate teaching end of the day's plan, and in what stage of a well-defined cycle of teaching the day's

work lies. Unity in purpose rather than in method is sought. However constant may be the subject matter of a course, the laboratory equipment and supplies, and the community interests and influences, the teacher and pupils are ever-changing factors in the teaching problem, and diversity in teaching procedure becomes inevitable in secondary school sciences. Then, too, while following such a "cycle" in teaching in order that monotony in class work may be avoided, and that the teacher himself continue to grow and be keen in his teaching, it is desirable and even necessary to vary continuously the manner of instruction, possibly the order of topics, and certainly the illustrations used and the applications made of the work.

Even the traditional arbitrary division of time into class and laboratory work does violence to educational processes even while it serves the ends of school administration. Where a certain amount of time daily has been set apart for a science subject, choice of a particular phase of the teaching cycle for any stated day or hour should be made solely with reference to what has largest educational value to the pupils in their particular stage of work. Indeed, the teacher should be wholly free within the limitations of the curriculum to change from any one teaching phase to another at will, and the order of steps set forth below should be modified or, it may be, wholly disregarded from time to time as conditions more or less unusual may require.

A Cycle of Science Teaching

1. A Class Period of Introductory Discussion:

(a) Assembling as class knowledge *what pupils already know as individuals.* Its use so far as this knowledge is usable in a study of the topic under consideration. Enrichment of such first-hand knowledge with further information imparted by the instructor in order to group and organize all of it according to its scientific relationships.

(b) Simple experiments performed by the teacher to serve as centers of new groupings of knowledge. The use by the instructor of inductive laboratory exercises, experimental and otherwise, to afford opportunities for constructive thought guidance.

(This necessitates an extensive acquaintanceship on the part of a teacher with the many phases of elementary science. A review of any work of previous lessons finds place here as an introduction to the new lesson).

2. Laboratory Exercises:

(a) These exercises must be such as to provide those particular experiences as "observations" wherewith to interpret what is to be brought before the pupils in the text as new knowledge, and for which the introductory discussions have prepared the way.

(b) Whether these experiments are to be performed

by pupils or by teacher will depend upon the subject, the nature of the experiments, the advancement of the pupils in science studies, the equipment, and other teaching conditions.

(c) Whether class discussions of experiments involving observations, inferences, conclusions, and applications in terms of the science studied shall accompany the experimental work, or wait its completion and write-up, will likewise depend upon teaching conditions.

(d) Laboratory exercises certainly should not consist exclusively of experiments. Very often there may be sets of questions to be answered sometimes orally and sometimes in writing, together with drawings, topical descriptions, and various kinds of mathematical and quantitative work. Excursions to industrial plants, to municipal or public utility enterprises, may be considered a part of the laboratory experiences.

3. A Study Period:

(a) Includes time spent in the laboratory in writing answers to laboratory exercises, both experiments and question lists. These questions should anticipate difficulties likely to be experienced later in preparation for a text quiz. A discriminating use of books becomes necessary in this search for information of a specific character. This is the time of all times to gratify desires of pupils for knowledge which is definite and

complete. Under guidance of the instructor there becomes possible a training of pupils in ways truly scientific in acquiring knowledge.

(b) Free use of text and other reference books allowed pupils during the write-up period provides needed assistance in vocabulary, in suitable expression of scientific facts, and for acquiring a scientific viewpoint of any problem under consideration. The text in its use here is a friend in need to the pupil and serves to supplement *but never to supplant* what the teacher can do.

(c) These laboratory papers after correction by the teacher, and when returned to the pupils, make up in large part the content of the notebooks. This combined use of reference books and experimental exercises is far more productive of educational advancement than is their separate and more or less unrelated use.

4. *Questions for Thought and Reference:*

(a) These are to be answered orally or in writing as their nature and teaching conditions shall dictate. Simple mathematical calculations *as applications of instruction given* are included, together with drawings and brief topical discussions.

(b) Some of the chief ends attained in use of these exercises are a training in acquiring facts (largely as information from books), and the organization of this information into definite, concise, balanced statements and discussions. This leaves for a later quiz on the

text only the parts which lend themselves best to a rapid-fire, question-and-answer exercise. (Use of the text here for recitation, and in preparing questions for thought and reference, may be outside the school room when teaching conditions seem to make it necessary.)

5. Quiz on Text Assignment:

Oral examination on an assigned limited portion of the text, ample opportunity for its mastery having been given. Or, a written examination to complete the consideration of several selected topics forming a unit of the subject studied.

Summary

1. Limitations upon exercise of an independent choice of matter and method by science teachers.
2. Needs of pupils as dominant factor in the teaching situation.
3. Purpose of introductory discussions of topics based on life experiences of pupils.
   (a) Usefulness of experiments in this connection.
   (b) Service to science teachers of prepared manuals.
   (c) Chief end to be attained through use of questions and experiments.
4. Usefulness of books of reference in general. Use made of them to give flexibility to teaching requirements.
   (a) Written work required. Its purpose.
   (b) The "Exercises" in a laboratory manual. Their nature.
5. Uses of a text in the "cycle" of science teaching.
6. Place and purpose of examinations.

7. Dangers of rigid adherence to a round of teaching procedure.
   (a) Advantages from following a "teaching cycle."
   (b) Degree of freedom of action to be reserved to the instructor.
8. The several stages in a cycle as summarized, and the significance of each.

PART II

CHAPTER XII

THE SCIENCE TEACHER

Aside from an aptitude and initiative and skill desirable in all teachers, and quite apart from all requirements of a scholastic and professional preparation or of a disciplinary and administrative character, a peculiar fitness and competency is demanded for success in science teaching in secondary schools. In the smaller high schools where the several science branches are all taught by one person, handicapped as such teachers often are by lack of suitable rooms, furnishings and equipment, the capable science teacher eager to accomplish for his pupils the educational possibilities of his subjects is likely to be the most overloaded member of the teaching force. In schools sufficiently large to employ a teacher for every science branch offered, or where the various sciences are parcelled out among the different teachers, the demands upon time and strength are commonly less exacting. On the other hand, in large high schools the many large classes require of the science teacher great administrative ability in order to give any individual attention to his pupils.

With a skilled teacher of large executive ability,

aided it may be by services from pupil assistants, there should be a large increase in teaching effectiveness by having instruction in several science branches given by the same instructor. Despite a possible tendency on the part of such a teacher to over emphasize one science at the expense of others, this arrangement in the smaller secondary schools is conducive to efficiency in the science work as a whole. Where one teacher trains a pupil in each of the several related sciences he can avoid too much duplication of work, and can readily provide abundance of opportunities for pupils to apply in one science what has been learned in another. Thus, for example, the gas laws of Boyle and of Charles learned in physics are applied in chemistry to the correction of gas volumes. If the teacher is a master of these sciences, he can give pupils something of their relationships in principles and in applications. Instead of giving isolated glimpses of this or that artificial subdivision of the field of science, the sole teacher in charge of all the science subjects has the possibility for such conservation of teaching energy that a real unification of the sciences is accomplished. That any full realization of these possibilities is rarely found is a matter of the personality and fitness of an instructor rather than of opportunity open to him.

In very many features high school instruction in several science branches overlaps, especially in those of composite nature such as agriculture and physical geography. General science as a subject in junior high

schools professedly recognizes no divisions of the natural sciences. Many of the same phenomena and experiments taught in general science occur in the succeeding courses where they may be reviewed rather than repeated without loss in teaching worth. Indeed, this "spiral" recurrence of essential topics is at all times highly desirable. What shall or shall not be retained from high school courses in botany, zoology, and physiology in the make-up of a year's course in biology is but an illustration of attempts to unify teachings of secondary school sciences.

Lessons upon combustion, centered it may be in the burning of a candle, serve equally well as an introduction to teachings about oxygen and carbon dioxide in chemistry; to ventilation and atmospheric conditions affecting health in physiology and hygiene; and to studies of convection currents, atmospheric circulation, weather and climate in physics and physical geography. In the teachings of all secondary school sciences a "general science approach" makes more certain many a teacher's success. Where pupils are plunged into consideration of subject matter without any preparation in knowledge of what is sought, and without any well-developed desire for attaining some end in particular, the haste defeats the teaching possibilities involved. That elementary courses in science shall be general in their teachings lessens in nowise the demand that always they must be scientific in spirit and in procedure. A course in general science, though com-

plete in itself as an educational unit, at the same time serves equally well as a foundation for further studies in the fields of natural science. Its success as a high school course, even more than for science courses of a more restricted scope, demands a superior degree of teaching ability and a mastery of teaching procedure in science instruction.

In laboratory administration even more than in the classroom the teacher's personality is indispensable. Character may be sufficiently defined as "what one is" —the sum total of his beliefs, mental reactions and emotions. It is the general state of mind of which one's behavior at all times is an expression. Personality on the other hand *may be considered as character in action* in so far as it influences, controls, and motivates others. Without a strong personality, the science teacher as a teacher is relatively a failure. This is not necessarily from any lack in disciplinary capabilities by which conduct in others is shaped as result of influences and forces *largely or wholly external to them.* But it is want of an impelling power which shapes character in others *by forces developed from within them.*

There is, too, a necessary amount of drudgery, of painstaking effort, connected with the experimental side of science teaching which in efficient teaching service can neither be shirked nor turned over to assistants. The instructor must *know his pupils as*

registered in the work done by them. This involves an intimate knowledge of the pupil's labored and halting efforts in the experimental phases of science, as well as what is learned of the individual pupil in classroom tests. It would be far easier for the instructor himself, in matters of technique and of thought expression, to do what he must patiently and persistently seek to have done by the pupil.

It may be taken for granted that it is largely out of question for the science instructor to train pupils in the art of study without himself possessing a well-defined understanding of what is involved in it. *He, too, should be a student.* The painstaking and consistent efforts necessary with beginners through the early stages of secondary school science to establish in them both a scientific attitude toward problems of life in and out of school, and a scientific method of solution of these problems, seems to be wholly impossible for some teachers *regardless of their information along scientific lines.* Their thought processes, and their outlook on the ways and purposes of science teaching, in large degree preclude their success. To be able to arrive at scientific conclusions, and to grasp scientific teachings by leaps and bounds, is in itself no mark of fitness for the training of pupils in elementary science. Lack of success in the first efforts of recent college graduates is not infrequently due to a lack of appreciation by them of the fact that their pupils cannot

master the beginnings in science courses at any such rate of acquisition of knowledge as they themselves have become accustomed to as college students.

Aside from differences in natural ability, the high school pupil has not yet acquired the art of learning to an extent supposedly possessed by his teacher. The beginning teacher succeeds only insofar as he recognizes the limitations of ability in his pupils, and adapts his course in teaching accordingly. A teaching temperament which day by day avoids monotony, and while giving attention to all important details at the same time moves steadily and methodically forward, is imperative in science instruction. If the teacher treats the quest for knowledge as though it were an interesting and purposeful undertaking, he will induce his pupils by imitation to put more effort into the work. Striking phenomena for teaching ends serve to challenge attention and to stimulate interest, and a judicious intermixture of these with the more exacting requirements aids in all sustained progressive efforts.

The guidance of pupils by the science teacher, especially in the laboratory work and its related lesson preparation, involves tact and sympathy. Especially must there be an alertness in noting just when and where to render assistance, and when to stop giving aid. To rob a pupil of the results he himself might attain through supervised efforts is to take away the joys of achievement, and with it the incentive to further efforts. But perhaps even more emphasis is

to be placed upon the need to steer a middle course between neglect on the one hand, and on the other those repeated interferences with a pupil at work, amounting simply to meddlesomeness, whatever may be the helpful spirit in which it is done. When pupils are not doing what is worth while, it is of course the teacher's duty to prevent their wasting time and effort. *But this interference is solely for the purpose of substituting something that is more worth while.*

Any discussion of science teaching in secondary schools is to little purpose where the qualifications of a teacher are minimized or ignored. Preparation and personality happily combined may so dominate any teaching situation as to win success despite lack of school equipment or indifference on the part of pupils. Indeed, pupils will not long remain indifferent under such a teacher. Some of the finest teaching, and much of the most significant research work in science, has been done by great master teachers and investigators whose material equipment was apparently utterly inadequate. The science teacher who is tempted to feel discouraged because of the poor equipment offered him may well take courage, treating his condition as a challenge to his ingenuity. With instructors unfit for science teaching by reason of lack of aptitude and personality, of suitable preparation in subject matter and in teaching procedure, no equipment however complete assures the educational values which are possible through science studies. It is not enough that science

texts and manuals of superior excellence be published, and laboratory furniture and apparatus and supplies be provided, and that finely appointed buildings with their suites of science rooms be erected. Advocates of the educational values of science studies in public schools must ever insist that well-qualified teachers of science be the rule in the small high schools even as in the large.

To be a success as a science teacher involves the exercise of no mean administrative ability, and a degree of executive talent, persistence, and initiative not unlike that possessed by the old-time housewife who in the farm home of earlier days contrived without aid of modern conveniences to spin and weave, to cut and mend, make and wash all the clothing worn by her household; to arrange the supply of foods for the family, and to cook and serve the family meals with all the kitchen labors incident thereto; and in a daily round of duties from early dawn to late at night find time to be family nurse and physician, instructor of childhood and a veritable helpmate and counselor to her husband in manifold business and social relationships. Pay by the hour for this labor, with "time-and-a-half for all over-time," was unknown.

There are duties and responsibilities and labors devolving upon teachers, too, for which no reward in salary is to be expected. No defense is made for the drudgery and barrenness of life experienced by the women of pioneer days, nor any advocacy of a return

to such manner of life, capable and proficient as the women who survived may have become in the hard school of experience. But emphasis is laid upon the fact that a teacher in public school service assumes certain duties and responsibilities *in loco parentis* which in nowise can rightly be ignored, and for which no salary as compensation is to be expected. In this field of endeavor the real teacher may become a powerful constructive influence for the embodiment in pupils of all those virtues which characterize the best types of manhood and womanhood. In it lies the largest degree of teaching success. One may well be doubtful if salaries paid will of themselves ever command the desired personality, instructional skill, and administrative efficiency required of science teachers. Nevertheless, judging from the past, in every generation there may be expected an idealism in young manhood and womanhood which sees in teaching an opportunity for service, and for some years of their lives at least this may be counted upon to make good to them what the pay check lacks.

There are not wanting some compensations which come to the successful teacher. There are leisure times between terms giving opportunity for study and, it may be, for travel. Then, too, the atmosphere incident to teaching service is different from that of the atmosphere of commerce, or of industry, with all their competition and strife. Best of all there comes to a life-long teacher, perchance somewhat tardily at times,

recognition by former pupils of services rendered them by him. Viewed in this light the work is its own reward. It remains true, of course, that the laborer is worthy of his hire, and that an adequate living wage for teachers should be provided. But under the operation of economic laws, and because of results inevitable where men seek first not the welfare of others but an exaltation of self, it is not in the nature of things to expect that financial returns from teaching service will ever measure up to its true importance as services rendered to individuals, to community, and to state. Undesirable as this condition is for teaching *as a profession,* and open to objections as it is in other respects, it does serve to attract an idealistic rather than a materialistic type of teachers, and to some extent at least to repel the self-seeking and the ignoble.

No amount of enthusiasm is a substitute for ability and skill in teaching; neither has science any large place for the dreamer and for those whose teachings do not rest upon the solid foundations of scholarship. In this connection, too, the general public with school boards as their representatives should demand of teacher-training institutions of high and low degree a maximum of emphasis upon a virility of moral as well as of intellectual life on the part of teacher-candidates. Evidence should be forthcoming of some reasonably well-matured convictions and beliefs concerning the relative worth of those various factors which influence young life for good or ill. One hundred per cent man-

hood and womanhood in the teaching force of the public school is fundamental to the welfare of society, and to the perpetuity of our American institutions.

An enumeration of science subjects represented in the curricula of high schools includes agriculture, astronomy, biology, botany, chemistry, general science, geology, physics, physical geography, physiology (taught with or as a continuation of hygiene and sanitation), and zoölogy. As these may be taught in all sorts of combinations in different schools, any adequate preparation as science teacher for the smaller high schools is scarcely to be expected, and any salary paid cannot be the sole solution for the teacher-problem here presented. A marked degree of general capability is necessary to the teacher confronted by conditions commonly faced by science teachers, and it must be listed as a prime qualification in all candidates. Educational agencies conversant with the available supply report year by year the number of "suitably qualified" science teachers entirely inadequate for the needs of the public schools.

Summary

1. Special fitness required for science teachers.
2. Advantages from having the same person as teacher of several sciences.
3. The teacher's personality characterized.
4. The instructor's part in laboratory work.
5. Fitness of teacher in order to train pupils into study habits.

6. Temperament indispensable to teaching success.
7. Wisdom and tact necessarily exercised by science teachers. Discernment of ends to be attained.
8. Importance of qualified teachers in science.
   General all-around capability of a science teacher.
9. Salaries as remedy for lack of qualified teachers.
   Compensations for teaching service other than salaries.
10. Science subjects represented in high school courses.

CHAPTER XIII

PROFESSIONAL PREPARATION OF THE SCIENCE TEACHER

However much in common there be in the aims and personal characteristics of those intending to become science teachers, any discussions of professional preparation for them of necessity follows a natural though rather vague line of cleavage. Separate consideration is here given to needs of science teachers in the larger schools as apart from those who teach in smaller high schools. It is a distinction between conditions where an instructor's work is confined to a single science contrasted with conditions common in smaller high schools where any sort of combination of science and other subjects may be taught by the sole science teacher, and where at the same time the science teacher may be the principal of the school and athletic coach as well. In one of these two fields the work undertaken and the preparation for it is very definite; the tenure of position and salary enjoyed is reasonably good. On the other hand, the teacher situation in small high schools is made doubly difficult by reason of economic and local controls. However, the persistent demand made by parents in behalf of their children's schooling, taken with or apart from college entrance requirements

and always in combination with the spirit of self-sacrifice on the part of a succession of enthusiastic teachers of science, makes an effort to maintain some approach to standard conditions for science teaching in small high schools not at all hopeless.

So far as choice of instructors for science departments of large high schools is concerned, and standards of teacher-fitness to which such instructors must conform, there is little need for discussion here. Presumably both the selection of teachers, and the power to fix and maintain standards, are in the hands of those whose capability is conceded. The success of any school administration depends in no small degree upon wise choices for a teaching force. The personal characteristics of science teachers is a topic which has been discussed. It is to be mentioned, however, that recognition more and more is being given to a need that science teachers even as other teachers be well grounded in principles of education based upon a knowledge of the psychology of teaching processes; that there be a sure grasp of teaching aims, and of the most direct ways in attaining these ends; that there be such a clearness of vision concerning social backgrounds for instructional efforts as reasonably assures marked success in teaching even before it is undertaken. It is not enough to have "specialized" in the particular science one undertakes to teach. By very reason of this specialization it becomes quite possible that a would-be instructor has alienated himself from interest in and

sympathy for those who as his pupils are merely beginners in science studies, perchance indifferent students at that. To fail of being conscious at all times in the teaching process of the outlook of pupils because one's own tastes have developed into more advanced fields of study not infrequently has proved fatal to success in the teaching of science in high schools. Success in teaching must be measured in terms of teaching children as distinguished from teaching subjects. The psychology of salesmanship has many helpful suggestions to teachers in securing from pupils the desired positive reactions to teaching efforts.

Inexperience on the part of a teacher not unnaturally mistakes the teaching of subject matter to be the end in view. Without guidance and constructive criticism through the first months of teaching endeavor a beginning teacher may not only fail to develop a well-grounded self-confidence as to teaching ability, but may come face to face with a disastrous close to a short-lived teaching career. In these failures the interests of pupils in schools most unfortunately are involved. For the welfare of pupils, and for the maintenance of a teacher-supply better fitted for science teaching in high schools, there is no satisfactory substitute for teacher-training.

A full major in some one science is a prerequisite for anyone who looks forward to departmental teaching of science in the larger high schools. This preparation in some one single field should give the whole setting

of that science—its history as to stages of development, its applications in the affairs of men, the most recent advances made in it, and the problems it presents awaiting solution through research. Lacking such preparation, one's advancement in rank and salary is handicapped if not prevented howsoever satisfactory that teaching service may be. In connection with this major, suitable choices of other science courses either physical or biological are readily made, possibly as a minor, giving a proper balance and perspective to the field of science teaching as a whole. With a thorough understanding and definite knowledge of science more extensive than the subjects to be taught, and with a spirit of persistency in well doing accompanied by an abundance of faith in the possibilities of youth, there must be combined as preparation for a life's work of teaching high school sciences a definite understanding of the theory and principles of education. These once were learned only (and well learned, too, in many cases) through experience, but always at the expense of hapless pupils. This preparation is possible at the hands of master instructors in the field of Education.

In turning to a consideration of professional preparation on the part of those who are teachers of science in the small high schools of the country, deplorable conditions are not infrequently noted. Any permanent betterment of these conditions must come in part at least through efforts of leaders among science teachers *possessed of a vision of what must be made true con-*

cerning science instruction before its educational values become a notable asset in high school teaching. It is well in this connection to visualize the condition that of 16,000 and more high schools in the United States two-thirds of them have 75 pupils or less apiece, and but 5 per cent of the high schools have an attendance exceeding 500 pupils.[1] Where science teachers in these smaller high schools have had some preparation for their teaching, it is quite likely to be inadequate in breadth of vision of the whole field of science as it affects the lives and interests of pupils. It is more likely to have been an intensive rather than an extensive preparation in subject matter for teaching. Moreover it is very likely that theory and methods courses in education have been so divorced from whatever subject matter is to be taught as to become mere abstractions, and in many cases but a shibboleth of the vocabulary of education, lacking in vital relationships and significance.

Courses in educational theory, history, and measurements are not infrequently taken by prospective teachers when they might better be engaged in a struggle with the difficulties incident to a shifting of viewpoint from that of a pupil under direction to that of an instructor upon whom falls the responsibilities of directing instructional processes. Methods of teaching a science often may be studied to better advantage in connection with the mastery of difficult portions of it

[1] Bulletin No. 19 (1920), Bureau of Education, Washington, D. C.

rather than wholly apart from its subject matter. Science students, too, by very reason of their science training rebel at having put before them as beginners a study of the theory of education apart from its facts. *To them theory develops out of facts,* and it is quite conceivable that "Education" in its first stages even as with science instruction should be inductive rather than deductive.

It is likely that differences of opinion will ever exist as to what constitutes suitable preparation for the exceedingly difficult situations confronting teachers of science in smaller high schools. Nevertheless, it is high time that frank recognition be given of a responsibility resting upon science teachers in active service in colleges and in secondary schools to join hands with teacher-training institutions to the extent at least of directing to these institutions young men and women who by natural tastes and special aptitudes give promise of becoming teachers of superior worth and fitness.[2] In any student body can be found certain "choice spirits" who in due time and in their generation may become capable of inspiring youth to seek the best there is in manhood and womanhood. These capable ones are to be sought out, and upon them should be urged the advantages, the opportunities, and the responsibilities for service social and civic throughout the years of their public school teaching. For them

[2] "The Teacher Supply in Science Subjects," *School Science and Mathematics* (XXII: 424).

a broad rather than a narrowly intensive preparation in science subjects should be combined with suitable courses in methods and practice which exemplify well-defined educational principles.

With such concerted effort as thus set forth the situation with regard to a teacher supply for science instruction in small high schools would be greatly improved, and as a problem it might disappear entirely. These better conditions would persist in spite of the endless "turnover" occurring in the teaching forces of secondary schools. Though but a small number of such students be found in any one science department in colleges, or in the science classes of any high school, the aggregate per year of those thus called to be science teachers would be large. Science teachers may thus extend their services to society, and as recruiting agents can promote better science teaching. It is suicidal for science departments of colleges and universities to maintain an indifferent attitude towards the standards of science instruction prevailing in high schools. In these high schools are trained the generations of those who are to become leaders in citizenship, and through whom must come appreciation of scientific achievements in relation to civilization and the industrial prosperity of a nation.

It is not asking too much to demand that none but suitably qualified and specially trained teachers give instruction in science. The extent and completeness of this preparation of necessity involves the laws of

economics, and a survival of the fittest. To this problem of teacher-supply various organizations of science teachers may fittingly apply themselves in seeking ways whereby to influence powerfully and persistently for the better all those conditions which affect the teaching of secondary school science unfavorably. In all such efforts little direct co-operation need be expected on the part of that great silent majority of high school science teachers never in attendance upon meetings of science organizations, and who are not reached as readers of publications for teachers of secondary school science. Let science organizations acting in conjunction with other effectively organized bodies promoting educational efficiency, and with officials of departments of education, insist upon and in due time secure tests of fitness for teaching science in high schools which shall serve as effective barriers to those who manifestly are unfitted for science teaching.

By what stretch of the imagination is fitness for teaching science tested by ability to "pass," with a grade of 75 per cent or upwards, an examination based upon a list of ten questions for which sufficient preparation is made by "cramming" the statements of some high school text in science, especially when this has been aided by study of lists of questions given in previous examinations through a period of years. Where in any such blanket tests for a Teacher's Certificate for "license to teach" not only high school sciences *but all other secondary school subjects* can be discovered

in a candidate "evidence of teaching skill and aptitude; of ability to reach just decisions readily; of mastery of teaching principles and teaching procedure; and of any wide outreach in general knowledge and in human interests distinguishing the teacher from a mere hearer of recitations." [3] All progress in science instruction in high schools fails of its full fruitage without competent instructors. The problem of schools must ever be one of the human element as embodied in teacher no less than in pupils. Let science teachers in service aid in its solution.

Summary

1. Differences in preparation to meet different teaching conditions of science instruction in large high schools and small.
   - Conditions determining choice of teachers, and their qualifications, in science departments of large high schools.
   - Risks to teaching success where an instructor has "specialized."
   - Teaching of pupils as distinguished from teaching subjects.
   - Fitness through courses in "education."
2. Importance given to teaching of science in the smaller high schools.
3. Character of preparation in "education" of science teachers.
   - Objections to nature and order of education courses required.

[3] "Betterment of Science Teaching," *School Science and Mathematics* (XXIII: 66).

4. Co-operation of college departments of science and teacher-training institutions for betterment of high school science teaching.

   Relation of the "problem" of science teachers in high schools to colleges and universities, and to society at large.

   Difficulties of the situation inherent in lack of interest of high school teachers themselves.

5. Teachers' examinations for "Licenses to Teach."

CHAPTER XIV

THE SCIENCE TEACHER AND THE COMMUNITY

The problem of social contact and community service for science teachers in the large school systems is very different from that for teachers in the smaller towns and cities. Special consideration needs to be given conditions which affect the life services of science teachers in the schools of large cities. No such social prominence and personal influence is as likely there as may be taken for granted in smaller towns. Special effort is necessary to attain and extend the influence on community life which science teachers may and should exert by reason not only of personality but as well because of what they are capable of contributing. It will be necessary to make sacrifices of time and effort, and perchance of money, to seize upon and hold opportunities for service other than those of a routine of adjustments within the mechanism of a highly organized school system. At the same time much of what is here said concerning these conditions affecting science teachers in large cities is applicable in some degree, and with modifications it may be, to science teachers everywhere.

Teachers as a class in contrast with doctors, lawyers,

engineers and professional men generally, are at times criticized adversely because lacking in professional and community spirit. A number of good reasons may be given for any actual lack in this respect. Chief among these causes, perhaps, is the fact that teachers as a rule have not been able to afford the expenditure necessary for an active participation in professional and community affairs. Another factor making against such activities has been the transient character of teaching as an employment, both as regards leaving the profession voluntarily after using it as a stepping stone to another profession, or in the case of women in order to marry. Then, too, there is uncertainty of tenure in positions, accompanied by frequent moving from place to place.

With the general increase in salary schedules of teachers during the World War period, and with increasing numbers of young people entering the teaching profession with the idea of making it their permanent calling, there should be a notable increase on the part of science teachers in professional spirit and in the manifestation of community spirit. Aside from the moral obligation which is upon all teachers as individuals, any such manifestation is profitable in the long run for all concerned. It tends toward an extension of professional prestige when the public takes note that teachers as a class make considerable expenditures in behalf of the interests of the community at large. It

repays teachers richly by increasing their personal influence, and the respect in which they are held.

What is true of teachers in general is especially and peculiarly true of science teachers. In this more or less materialistic age people are prone to have a superior regard for that which they see is immediately useful. Among the many lessons of the World War, people learned that science is exceedingly useful to mankind. They became convinced that science subjects are very much worth while. Science teachers are on this account in a position to get more readily, perhaps, than other teachers the support and approbation of the public for any efforts toward a better professional and community standing. It devolves upon us to use this advantage in a spirit of *noblesse oblige*. It is the purpose of this chapter to point out in concrete ways how to go about improving the situation.

The extent to which the following suggestions may be carried out will depend largely upon circumstances such as the size of the city in which one lives, governing as this does his opportunities, and upon the salary which one receives. Personal and family obligations, too, enter into these situations as between teachers on similar salaries. While no extravagance in respect to expenditures for professional advancement is urged, a short-sighted parsimony has too often been true of teachers. It is the part of wisdom for teachers to expend time and energy and money in order to in-

crease their own influence, and the prestige of the teaching profession.

Probably the first definite step to be taken by a science teacher looking toward the advancement of his professional interests is to join some scientific society representing his major line of interest. A national society with its important journals, and its large membership and influence, is usually to be preferred when one is so situated as to be able to attend meetings of its local sections. One should seek opportunities of coming in contact with people interested in his own particular field of science. At meetings of scientific societies those who are applying the science in industry, or making original investigations in it, meet with those who are teaching it. A teacher is thus mingling with men who are in the forefront of his particular field of science. He keeps up-to-date as regards discoveries made, and all new uses of his subject. He may find parts of his most recent textbooks out of date, but he is able to keep his pupils abreast of all advances made.

On his part the teacher will have his influence on the industrial men. They will find that his work and theirs have much in common. Membership in a scientific society brings with it, too, an opportunity and an obligation to prepare and deliver from time to time articles upon various topics connected with the society's interests. The teacher frequently can do this to better advantage than an industrial worker in science. Es-

pecially is this true when some of the more theoretical and historical parts of a subject are involved. The teacher has brought to him in turn the details of applications of his science, and a live human fellowship. A teacher, too, usually can give the time to serve as an officer, especially as secretary of a section, even better than an industrial man.

The science teacher should not neglect opportunities for community acquaintanceship and service offered by his own church, the local lodge, the chamber of commerce or board of trade, establishing for himself in all their fields relationships mutually beneficial. To their credit it may be said of teachers generally that they do not as a rule fail in support of those various agencies which promote social, moral, and religious betterment. The hard-pressed forces which struggle under heavy handicap to maintain some sufficient amount of religious instruction in American life have reason to expect of science teachers some portions of their time and teaching ability, and such other support as they are able to give.

Within his own school the science teacher can reach his community through a science club [1] with open meetings to which parents and friends of the pupils are invited. The personal acquaintance with some of the grown-ups which is thus fostered is valuable. The parent-teacher organizations, now so widely prevalent, offer to the science teacher as to other teachers an op-

[1] See p. 317 for suggestion of work for such clubs.

portunity at community influence which should be grasped. Opportunities in a social way to meet with school officials should be sought and improved. Acquaintance with them is too often limited to such contact as becomes necessary in a business way. In large cities and towns a school men's or a school women's club formed largely for social purposes is valuable. It should include in its membership not only school board members and executive officers such as superintendent, assistant superintendents, principals, supervisors, and vocational directors but as well the rank and file of the teaching forces. One should also be an active member of state and national educational associations.

One of the most direct and positive ways for a science teacher to get into touch with community interests is to visit industrial plants which apply the science he is teaching. On the first of these occasions the teacher should make a visit by himself; then, if conditions permit, classes can be taken later to note any certain stages of the work. A little tact may be required on the first visit in order to avoid unnecessary rebuffs. It will be best to first approach some higher official in the organization who appreciates civic relationships. Access to nearly any plant may be gained where there are no unusual dangers. Care must always be exercised on such visits to keep pupils out of danger from moving parts of machinery, etc., and to avoid so far as possible all interference with employees at their labors. The time spent at the plant must be as brief

as will suffice to illustrate the matter in hand. A little publicity for the firm should be given in the school and local papers in connection with the trip. This is good publicity for the school, too, when written up as real news. These trips are to be taken in school time whenever possible to do so without interference with other classes, thus permitting attendance of every pupil of a class. After-school or Saturday trips may be necessary to reach factories or municipal plants having to do with water supply, or sewage disposal. Such excursions offer a splendid opportunity to get acquainted with pupils as well as with community interests. Rightly used they are among the most effective means of teaching.

Science teachers especially well equipped in their major subject can be very helpful to industrial concerns from time to time as problems arise in those plants. Acquaintance with such problems may develop from the visits just discussed, and every opportunity for the science teacher to be of assistance should be grasped. Such services may mean the making of calculations which involve a knowledge of chemistry, such as a water-softening problem or a cleansing operation. In most cases the well-trained science teacher can successfully apply his technical knowledge to a speedy solution of some such minor problems, and by so doing get the regard of the manufacturer for himself and for his school. Whether or not one should accept a fee for such services will depend in part upon

the value of the results, and the amount of time and skill required for the solution of such problems. Where the work is done entirely outside of school time, and is strictly without interference either direct or indirect with school work, there can be very little objection to asking and receiving a reasonable fee.

Another community service that technically trained science teachers can render is helping out the purchasing department of the school system. Chemistry teachers especially can be helpful in this way. School authorities at times buy at extravagant prices under fancy names cleaners, soaps, water softeners, etc., which might be had under their true names for very much less outlay. A simple examination will easily determine the nature of most of these things. The purchase of materials under exact chemical specifications will be made possible where the chemistry teacher is able to check their nature by analysis. Purchases of coal in large quantities may wisely wait upon specifications as to heat values. Tests to check values of deliveries can be made by pupil assistants working under direction. Such pupils are always greatly interested in these "real problems."

In rural communities science teachers will find many opportunities for helpfulness in connection, for example, with the office of a county agricultural agent. Identification of injurious insects, prescribing methods of combating their ravages, use of spray materials for insects and for plant diseases, preparation of these

spraying solutions, testing and treatments of seeds preparatory to planting, together with various simple soil tests, suggest some of the many things which can be done by a science teacher whose knowledge of his subjects embraces their applications in life's affairs.

When a science teacher follows a course somewhat as outlined above, it is not long before an acquaintanceship is gained which will enable him to perform that exceedingly useful duty in community service in the placement of many of his boys and girls at graduation in positions which they are capable of filling. This service has a double value in that it is advantageous alike for employer and employee. A science teacher usually comes to have a pretty good notion of the ability, the degree of willingness to work, and the special inclinations of his pupils. He can in no small measure avoid trying to fit "round pegs into square holes." In many cases an especially bright pupil lacking the means to go to college may be placed where he can earn the necessary amount to make a start, and in a place where he will be encouraged by his employer to take the time to continue his studies. Part-time jobs can be found for pupils who need to earn some or all of their expenses while in school.

With a few years of experience in making careful selections of candidates for positions, the science teacher will find himself called upon to supply more and more graduates. Thus it comes about that both the community and the particular individuals served

profit by reason of the intimate knowledge of pupils gained by a science teacher through years of service in classroom and laboratory. This intimacy is peculiarly the privilege of science teachers, and these services rendered are wholly supplementary to their other labors as teachers. All remuneration lies, of course, in the satisfaction derived from having served well where service was greatly needed.

Summary

1. Criticisms of teachers generally for lack of community and professional spirit, and lack of co-operation with helpful agencies.
2. Opportunities of science teachers to overcome adverse criticisms.
   Comparisons with opportunities had by teachers other than in science.
3. Suggestions of specific things which can be done:
   Active affiliation with national, state, and local scientific societies.
   Magazines, and published reports of proceedings.
   Writing as well as reading papers on science subjects.
   Local clubs, lodges, church work.
   Science clubs for pupils and school patrons.
   Parent-teacher associations.
   Personal acquaintanceships with parents, school officials. Teachers' clubs. Visits to local factories, shops, municipal plants.
   Technical assistance to local manufacturers, to purchasing department of the school system, to agricultural and horticultural interests.
   Employment or placement service.

CHAPTER XV

THE SCIENCE TEACHER AS A BUILDER OF CHARACTER

When contemplating the achievements of science during a generation, and when considering ways and means to keep instruction in secondary school sciences abreast of scientific progress insofar as its applications and theories affect industrial and social life, educators very naturally point to expensive buildings and equipment, to adequate provisions in apparatus and libraries, and to the many secondary school science texts and manuals of superior excellence as sufficient evidence of educational advances.

However, when due credit has been given for this wonderful array of resources for science teaching, they are a means only to the end desired. It is efficient manhood and womanhood which must ever be the primary object of school instruction and training. No subordination of this chief end of educational processes to the means employed in attaining it, no loss of development of individual lives by reason of striving for greater efficiency in the mechanism of school administration, can be justified.

It is one thing to allow that the chief purpose of schools and of the subjects taught in schools is the

upbuilding of manhood and womanhood in individuals, and to say that well-balanced, properly-developed personalities are indispensable for the perpetuation of social order and progress. It is quite another matter consistently to pursue feasible plans toward accomplishing such an end. In order to preserve itself society must conserve not alone human attainments in knowledge but as well the ideals of mankind for moral and spiritual uplift. Instruction and training in both of these must go hand in hand through childhood and youth. The most efficient school system, and the most effective ways of teaching, are wholly compatible with such a deterioration in morals and such a lack of ideals as to become a menace to civilization, and to the demands of humanity for freedom and self-government. Any teaching of the sciences however well done can never justify itself in an American public school system when it loses sight of the supreme end of education —exaltation of character.

The greatness of the science teacher as of all teachers is measured by the kind of men and women developed under his instruction. His teaching service must assume its full measure of responsibility for the views held and the efficiency shown by them. The teacher, in theory at least, is a constructive force for nobility of character in the lives of those coming under his direction in school. This problem of the schools transcends in importance all other teaching duties and responsibilities. In the smaller high schools, and in the

smaller communities, a science teacher has exceptional opportunities for exercise of personal influence in character building.

An ability to make decisions is fundamental in all who are called to fill positions of trust and responsibility. It must be an ability to decide quickly and wisely under any and all circumstances, and to grasp conditions accurately and comprehensively. With this, too, must be the certainty that knowledge of what to do *assures its being done. And in this assurance lies the test* of whether or not the character-building process going on in homes and schools, and by reason of the various agencies of social and civic life, is succeeding or is a failure. Whether in jails, or not, most of those who are a menace to the peace and security of society *"know better,"* but their enlightenment failed to react aright in their own lives and in their civic relationships. There is no new and different psychology for moral and for mental integrity and soundness.

Lack of ability to come to well-considered decisions upon questions of moment, even those by which are shaped the issues of life, is deplorable. Rarely does vanity, or mean ambition, or gratification of self and of the baser things of life, become a ruling passion through deliberate choice and intent. It should be added, too, that a well-ordered life avoids those ways which the experiences of others have shown to be unsafe. No ship's navigator tries to see how close to the rocks he can run without shipwreck. Decision of char-

acter is in no large sense an accident of birth, of surroundings, or of circumstances. In all members of the human family it is a latent power waiting development by well-defined processes much as the body grows and waxes strong, intellect expands, and reason becomes powerful. Therein lies the possibility of a school and home training which shall include character development in conjunction with growth of body and of mind.

In infant life no fact is more apparent than an incessant physical activity coincident with a healthy sturdy growth of body. This necessitates an ample supply of suitable materials as food whereby the building up of muscle and bone, of blood and sinew, of nerves and various other organs is made possible. Somewhat similar conditions and limitations prevail in the realm of intellect whether studied as brain development or apart from it. An exercise of mind is involved in all thought processes. Thinking may be considered as essentially an act of establishing relationships between facts. No subject in the curricula of secondary schools justifies its place save that through use of its facts and theories the mental processes of pupils are stimulated, their mental habits established, and the material for thought provided in larger measure than by use of other alternative subjects.

Training for efficiency in schools does not seek to make skilled operators of the machinery of business and industrial life, nor on the other hand successful bidders for public favor in professional or political life

as ends in themselves. Instead there is to be sought those higher aims summed up in the familiar phrase "character-building," a training which seeks to develop in individuals the two-fold power of being able to choose aright and to execute effectively. We are astonished at times to note the rise in the affairs of the world of a boy thrown early upon his own resources into the thick of a struggle for existence. We marvel, too, at times at the little accomplished by some well-schooled youth whose mental and physical endowments appeared equally good with the other. Oftentimes, in such cases, it requires but little inquiry to discover that he who made his way unaided of schools, and by reason of sheer energy well directed, has what the other lacks—an ability for close definite observation, a readiness and keenness in inferring those relationships between facts which as inferences are true to the facts involved. If a boy has spent from sixteen to twenty years in school and lacks power to grasp the facts of his surroundings in any of the common situations of life, and is unable to reach quickly conclusions of his own based upon such facts, whose fault is it? It is equally pertinent at this point to inquire how school training may be shaped to contribute a maximum in readiness of decision, and in accuracy of conclusion.

Whatever explanations are advanced by the psychologist for any acquired readiness in grasping conditions and in establishing relationships of facts, for any unity between thought and execution or between any act and

that which prompts it, it is a matter of common experience that execution is perfected, is more speedily accomplished, and is accomplished with less effort *as the result of practice.* Any habit, either of thought or as a muscular act, results from much repetition of it in a particular way. The violinist acquires by long and arduous practice a control over the muscles of finger and arm whereby melody seems to flow from the finger tips.

Education essentially is a matter of habit formation, not merely a familiarity with the contents of books. To be educated is a matter of prompt reactions of an habitually right sort to the stimuli of life's experiences rather than an ability to answer lists of questions in examinations. And this is none the less true in spite of the fact that credits and graduations and degrees must continue to be granted in large part upon the evidence of knowledge made manifest through examinations. It is so easy to mistake the means used for the end sought! In health teachings in schools, for example, lessons in hygiene and sanitation furnish a good illustration of the difficulties attendant upon educational efforts for habit formation, and the scant success too commonly attained. The immediate end of all instruction by teachers concerning health control is granted to be *a fixation through practice of health habits* conducive to individual usefulness and happiness. Studies of health and hygiene in their impor-

tance rank among the first in all courses in schools in spite of a wide-spread neglect of them, and the generally unsatisfactory teaching results from them.

Any well-developed plan of instruction concerning health control, including inhibition of desires and rejection of suggestions leading to questionable courses in life, does not consist alone of the instruction given, necessary as this may be. It lies rather in a continuous stimulation of effort, and such sustained guidance in life's ways as necessarily result in an habitual reaction to whatever promotes well-being in both individual and community life. The same problem is met, both in its instructional and its training features, in a character-building process in the domain of morals. Educational advancement primarily then, whether the moral element in an individual's life be included or excluded, is a question of what one is and is to become, of what one has done and is able to do. It is a matter not of apt phrasing of statements of the achievements of others, but the characteristic behavior in thought and act of an individual himself. A science teacher's concern in all instruction given is to secure in the lives of his pupils that degree of scientific attitude and scientific procedure the natural outcome of which is a sanely ordered life in matters of health and morals, and in domestic, civic, and industrial relationships. To measure up to the demands thus made upon science teachers, men and women are needed who are possessed

of superior worth and ability wholly apart from and in addition to their knowledge and skill as instructors in science subjects.

The public school by its instruction and training is supposed to fit for a better discharge of life's duties and responsibilities. There must be provided the largest possible opportunity for growth in power to decide. This can best be secured through long sustained practice in making decisions. Any such training is to be continued until decision and execution habitually follow consideration of the facts of any situation. Although it is the ability to think which is the desired end in school work rather than any specific thoughts as knowledge content, this ability comes only as result of having done much thinking. Thought is in itself a grand achievement of the human mind, but the power to think is a still grander thing!

Decision of character as an aim of school training can be gained only where opportunities for decision have been presented *and decisions insisted upon.* He is accounted a teacher of worth who so arranges his work as to require of his pupils a maximum of mental effort. How much more worthy is he who with all this, and in connection with it and at the same time, secures through well-directed, well-sustained efforts *the power to decide.* In the make-up of a man or woman *no characteristic is more of an asset than readiness in reaching decisions which are in accord with the facts involved.*

While any particular course pursued to attain these ends must take into account the individuality of the teacher, the subject taught, and the conditions under which the instruction is given, this general procedure may be followed:[1]

(1) In the numberless questions asked in science classes by teachers let the outstanding purposes of these questions ever be to provoke thought, to direct it to certain desired ends, and to drill upon instruction already given in order to emphasize it. No teacher needs to be told that to gain such complete control of the thought of every pupil in a class as shall make possible throughout a class period a sustained mental activity in unity with the class as a whole, with every pupil mentally alert and doing "team work" in a progressive class thinking, taxes to the uttermost skilled teaching powers. Beyond a doubt the weak link in the chain of teaching procedure, usually, *is the fact that but one pupil at a time* struggles with the difficulties of formulating and expressing thought as an answer to each one of the successive questions asked. All others of the class for the time being wait passively for their turns to recite. It renders unlikely that continued mental tension requisite to the highest teaching values. Inevitably *thinking as a class* deteriorates into thinking as individuals, and this in turn into thinking upon diverse topics unfruitful it may be in teaching values. The teacher, in supplying a motive for these

[1] See pp. 118-121.

individual efforts, arouses one pupil after another in turn from passive to active mental conditions, only to see this activity lapse again into indifference as another pupil is subjected to questioning.

(2) Let the ideal of class management be *to get every pupil to answer every question asked,* allowing no opportunity for relaxation in mental activity from start to finish of the class period. Obviously such answers to questions cannot be oral—one pupil only can be called upon to speak the class thought. All answers are of course subject to corrections and amplification by other members of the class, and especially by the teacher. Use of the class period daily for any extended written responses, whether as a quiz or examination, is impracticable because of the burden thrown upon the teacher in reviewing these papers. Opportunity for instruction by the teacher during the class period—the vital purpose of the class session—then becomes seriously restricted if not eliminated.

A class procedure is desired which when consistently followed yields in educational advantages much the same results as would accrue if every pupil could by some means give expression independently to his thought *in answering every question asked by the teacher.* The simple expedient (p. 62) of expecting and insisting that pupils "raise the hands" *indicative of a readiness to answer* all questions asked for which they are able to formulate an answer, is an expedient to which teachers in the elementary schools are driven

in order, it may be, to repress and control expressions of mental effervescence. A like procedure in class management in secondary schools *can be made to promote and sustain mental activity otherwise deplorably lacking.* Incidentally, too, it makes uncomfortably conspicuous, any pupil or pupils who for any reason are unable or unwilling to do team work responsive to the teacher's leadership. Questions are easily framed from time to time so easy to answer that the dullest pupil in class cannot plead inability to answer. Cases calling for change in class membership, and a need for disciplinary measures of some sort, are soon apparent.

(3) Let it be considered that one chief value of the raised hand in response to questions asked lies in the implied expectancy on the part of pupils that anyone whose hand is up is likely to be called upon at any time, and possibly time after time. With one only called, it does not to any degree rob the others who have all formulated answers to a question asked of the mental exercise and educational value this becoming ready to give an answer has involved. The series of demands for organizing knowledge to answer question after question, when taken in connection with explanations, comments, and contributions of facts by the instructor, makes of the class period an intensive and sustained thought exercise of highest educational worth.

However, there is another phase of this class management with which we may well be more particularly

concerned. It is conceived to be true that the excellency of this class procedure lies in the fact that every question asked gives opportunity for every pupil in the class to make decisions—decisions (1) as to an ability to answer; (2) as to what answer to give, *i. e.,* its form, and content; and (3) what is, perhaps, the vital matter—whether or not this answer shall be offered voluntarily, inviting to itself criticism and possible rejection by the teacher. Schoolroom training must fit for the affairs of life outside school. He who accomplishes much in life's work *must be able to set himself to its tasks,* must take the initiative and must face possible failure through error in facts, or in reasoning, or in giving wrong or incomplete expression to what is in his mind. *If he wait for the world to force him to act,* to put into his possession the exact bounds for his activities, he is unlikely ever to take an active part in its affairs. When in our schoolrooms we call a pupil to his feet, and then ask him a question, we have by this very act *robbed him of an opportunity to take the initiative himself in answering.* His effort to answer is by reason of compulsion. He does what he is told to do or in too many cases endeavors to evade doing it. His mental activity is abortive of growth and power. He does not decide for himself whether or not he is in possession of such facts as to warrant an answer; whether or not he sees clearly any relationships among these facts; and whether or not, of his own initiative, to attempt an expression of his views.

Real educative processes require the instructor to encourage, to stimulate, to lead on to well-considered ends the natural activities of those who are to be educated. In the kindergarten the child is repeatedly called upon to choose, to decide for himself, *and to abide by his decisions.* To make the importance of right choices apparent, to encourage thoughtfulness and constancy of purpose, to reach deliberate and well-considered decisions, these choices when made must be regarded as binding. They are to be set aside only when after deliberation a wiser choice may be substituted. Where in schools beyond the kindergarten is special training to this end found? Where in school and home training of children and youth is due emphasis placed upon the importance of decisions deliberately made, and the binding force of them recognized when made?

For any original thinking from members of a class there must be furnished something to think about. It must be so presented with reference to existing conditions as to make this thinking of largest value. It is the teacher's part so to arrange his class work, and so to put his questions, as to make independence and originality of thought not only possible but the only acceptable kind of class work. The importance and value of well-considered judgments based on known facts is at the same time magnified, and any conclusions deliberately reached must not be lightly changed or discarded. In all cases as far as possible these con-

clusions are to be reached upon the initiative of the pupils. Whether the subject be a science with its many phenomena for explanation and classification, or one involving the study of mathematical or artistic forms, whether history from original sources or a subject from any other department of school work, much more can be accomplished by keeping constantly in view such aims as are set forth above. The emphasis laid upon making decisions, and their binding force upon the conduct of the child in the kindergarten, may very well be made prominent in all school administration.

Since the exercise of the child's powers of thought is of greater importance at this stage of his development than the result of his thinking, teachers by way of encouraging pupils to think are justified in accepting from them, always of course with reservations, more or less incorrect and imperfect products of their thinking. More credit may be given at times for use of "horse sense" though misdirected, than for correct answers obviously not original. It must be that the value of an acquired habit of original thinking cannot be appraised at its full valuation by teachers, else why such neglect in requiring it of all pupils to the full measure of their abilities?

Teachers need to exalt in their own thinking the fact *that it is their province to make the conditions for mental growth,* to give opportunity for thinking, and to insist that thinking be done. Above all they ever are to keep in mind that growth is through exercise in

the individual himself, and through his appropriation of the facts which as "thought material" may be brought before him. For this growth there must be activity—an activity to be guided and not repressed, encouraged and urged and insisted upon—*an activity from within.* There is no growth in an automaton though when wound up and set going it repeats the words and the very inflections of our voices, and gives forth without error set forms of words for the correctness of which it might well claim a mark of 100%. There must be life, and an activity responsive to every effort to lead it out and to direct it. Take away the material for thought, and the necessity for thinking, and the intellectual life languishes and is stunted. With no suitable exercise of thought effort whereby conclusions wholly original are reached, judgments formed, decisions made by self-initiative, there results enfeeblement of mind rather than strength, deterioration rather than growth. The so-called self-educated man learns early to think for himself, to rely upon his own judgment, to decide quickly, and to act for himself.

THE FUNCTION OF TEACHERS OF HIGHEST IMPORTANCE IN THEIR DAILY ROUND OF TEACHING DUTIES IS SO TO TRAIN THOSE UNDER THEIR CHARGE THAT THE POWER TO REACH DECISIONS FOUNDED ON FAIR DELIBERATIVE THINKING SHALL CHARACTERIZE THE FINISHED PRODUCTS OF AMERICAN SCHOOLS.

Summary

1. Evidences of progress made in the diffusion and application of scientific knowledge.
   (a) Evidences of the worth of science in educational processes.
   (b) Elements to be conserved in all advances made in education.
2. Measures of success in science teaching.
3. Decision as a characteristic of a successful life.
   The importance of training for its development.
4. Means necessary for mental development.
   How character is developed.
5. Primary factors in a mastery of life's affairs.
   (a) School training to this end, or lack of it.
   (b) Habit formation as an end in education.
6. School training for decisions by pupils.
   Demand upon teachers in order to accomplish this.
7. The chief educational purpose of questions asked of pupils in class time.
   (a) Use of questions to control class thought. Ideal in management of class to secure this end.
   (b) Value of raised hands in this connection. Possibilities of a disciplinary character.
   (c) Three-fold opportunity for decision-making in connection with every question asked.
   (d) Causes of failure of school work to secure in pupils powers of coming to well-considered decisions of enduring worth.
   (e) Importance of considering decisions when once made as of binding force.
8. When only are constructive thought processes to be maintained.

(a) Teacher's part in this process. Moving appeal in requirements made of pupils.
(b) Characteristics of the so-called "self-education" as distinguished from much schooling.

CHAPTER XVI

PHASES OF SCIENCE TEACHING IN MORAL EDUCATION

In connection with a training in school to be prompt in making decisions of enduring worth, and along with a round of teaching procedure specifically directed towards habit-formation as a character-building process, the science teacher must ever be keenly alive at all times to what constitutes the supreme aim of all educational effort. Continuous close attention to the details of routine teaching processes tends to dull the teacher's vision. To guide beginners in science so that in due time they may become able to walk unaided the pathways of scientific achievement is a worthy aim. But if this be a purely intellectual process it is not enough. The responsibilities of the science teacher for manhood and womanhood as a product of the classroom and laboratory are to be measured by the opportunities in science teaching for shaping aright the lives of pupils under instruction.

It is necessary to be always conscious of what kind of habitual reactions to life influences are desired; what habits contribute most largely to individual welfare and to advances in civilization; what manner of daily teaching procedure consistently followed, and

tactfully adapted to changing moods and conditions affecting child life, promises not only keenness and capability of intellect but a sane and positive moral life. These are aims of primary importance in public school education, and upon their attainment through the public schools rests no small part of the hope that ours is an enduring civilization.

Promptness and positiveness in reactions to natural and social surroundings are notable characteristics of that growth into manhood and womanhood sought as the chief product of public school education. The ideals, aspirations, and beliefs of the race as to what constitutes right ways of living are a precious heritage to be transmitted from generation to generation, and from individual to individual, as "Wisdom of the ages." Any adequate round of school instruction can be made to include, in addition to its information and a training in effective thinking furnished by its course, *a wisely planned period of training in which application is made of life's ideals to every-day affairs.* Life's activities may thus be brought into accord with its aspirations and beliefs. The conduct of an individual in his reactions to life situations is an index to, and in the sum total of those reactions is an expression of, that intangible though very real existence known as character.

Merely to tell pupils what is desirable in life just as a matter of imparting information is relatively an easy task; but it is likely to prove even less effective than lecturing to them on scientific topics. To bring

about an embodiment of it in their life-practices taxes the skill and endurance of devoted teaching service, and all teachers can expect to experience more or less of chagrin over failures to accomplish these highest aims in teaching. Efforts to determine quantitatively by means of schoolroom quizzes whether or not there is manifest any uplift in the aspirations of pupils is likely to prove fatal to the ends sought. Character development is best tested out in the conduct of individuals under normal life conditions. It is not measured by an ability to formulate definitions in ethics, and rules of conduct for social, business, and religious life. In ethics as in elementary science, all assignments in books are for supplementary purposes only, enriching the teaching content and giving to it concise and suitable expression in a wisely chosen vocabulary.

On the other hand, the changeable conditions of school life as controlled by the teacher are akin in no small degree to life situations, and give ample opportunity and incentive for testing-out processes wherein conduct can be guided in its right expression, and right ideals become established. The chief guarantee against complete discouragement on the part of teachers over negative results experienced in the training of boys and girls, from the years of early childhood on through their youthful activities into a manhood and womanhood of high ideals and rightly-ordered daily living, is a clear vision of the complete "cycle" of teaching procedure. It requires (a) that the procedure followed be

based upon educational principles; (b) that it be adaptable to all normal teaching conditions; and (c) that when consistently followed it be reasonably certain in due time to yield in some considerable measure the results desired.

Though all pupils cannot be expected to benefit alike from equal opportunities in the American school system, it is none the less demanded that every child be given these opportunities, and be expected to make the most of his natural endowments. This must be insisted on both for the welfare of the individual, and for the good of society generally. A veritable army of instructors, acting in conjunction with other uplifting agencies affecting child life, must be kept at work the country over striving to attain for every generation in turn, and for the individuals therein represented, a degree of educational advancement equal to and perchance excelling that of earlier generations. Whatever the emphasis placed upon social, economic, industrial, or purely intellectual phases of education, and whatever the special procedure necessary to stress any one of these, fundamental to them all is an unceasing effort to attain in every life the best of which it is capable.

Along with every phase of educational advancement must go such a translation into conduct of a knowledge of right ways of living as shall inevitably yield in every life the best it can attain. In immorality lies the way of destruction of humanity. In non-moral educational agencies there lies no hope for civiliza-

tion. Instruction in schools which fails to incite pupils to sustained efforts intellectual and moral, and which fails to establish an abiding lifelong desire for knowledge and righteousness, has in it possibilities only rather than any realization of true educational advancement. Instruction in and of itself is as seed whose growth is assured *provided favorable conditions are maintained.* This is no less true in the realm of moral education than in other phases of intellectual development.

A large measure of attention must be given towards securing that state of mind in pupils characterized as teachableness, even as in agriculture it is necessary that soil conditions at seed-time shall be made such as to warrant reasonable expectations of a bountiful harvest. In all teaching there must be a continuity in the use of wisely chosen stimuli corresponding roughly to wisely persistent crop cultivation. As in agriculture where failure of a bountiful harvest is invited by an excessive amount of seed, the young plants having to make a struggle for existence, so it is in teaching. An overabundance of information *as facts only,* poured out upon pupils in unreceptive mental conditions, is unlikely to become fruitful in constructive thought processes. It tends rather to deaden and perchance it kills all desire for the "knowledge learned of schools."

Education is not inaptly described as progress in attaining an attitude of mind, and a readiness in mental reactions, which makes the individual habitually re-

sponsive to all influences and situations in life that are uplifting in their effect upon him individually, and helpful to his fellows. These responses *when habitual* free the mind for attention to other things, and furnish opportunity for further advances in knowledge and in intellectual capability. Character formation is not measured by the number of years of one's age. Normally, indeed, there should come with advancing years the putting aside of childish things, and of those mental stages characteristic of childhood in their uncertainties and changeableness. In place of these should come well-founded decisions suitable to intellectual maturity and of abiding value.

The dependable, safe-and-sane American citizen is he who has come almost instinctively to do what duty requires, and whose response to every situation affecting others as well as himself *waits only for information enough to determine what is the right thing to do.* To hesitate over doing the right thing, to postpone doing it, to seek to evade duty, to consider at length whether or not one can with regard to his own safety do what he knows should not be done, stamps one as yet a child so far as real manhood is concerned. Such a lack of right reactions, occurring habitually in an individual as though by instinct, makes him a source of weakness rather than of strength in society, and an undesirable type of citizen however brilliant his intellectual attainments.

It would be out of place here to give any extended

discussion of habit formation as a modification in brain structure, and as a development of connections between nerve centers whereby there becomes possible a re-routing of oft-repeated impulses of the same or similar character so as to demand a minimum of serious consideration on the part of an individual. But the educator in general, and the science teacher in particular, faces a consideration of whether or not there is lacking the educational results to be expected from the vast expenditures of time and effort in public schools; and if so, whether any such lack may not be traced directly to want of continuity in habit-forming thought processes throughout the years of school life. *There needs to be much repetition of a round of well-defined mental processes,* involving a clear discernment by pupils of what is sought in every cycle, and what is necessary to its attainment. This is as true, too, in moral as in scientific training, and it is an entirely different thing from the drills of elementary schools designed to co-ordinate sensory and motor impulses. The habit sought is concerned with general mental processes, and is one which stimulates rather than limits initiative and constructive thinking.

In science teaching the remedy for this lack clearly enough is not an additional amount of information—not more facts for which the pupil neither cares nor is prepared. There is no insurmountable difficulty in agreeing upon a round or "cycle" in elementary science teaching adaptable in practice to all secondary school

sciences and capable of being followed consistently year after year throughout school life. Its chief purpose is to establish in every pupil a mental attitude characteristically scientific, a right reaction habitually to life's varied interests. In it there must be no undue amount of monotony caused by repetition of words from books, nor lack of variety in the teaching material used and in the manner of its presentation. There must be a never-ceasing demand for constructive thinking, and for sustained efforts to gather and relate thought material, as well as for testing by application the validity of all conclusions reached.

A striking similarity appears between the procedure followed in moral education and in elementary science. Certain general principles of science teaching are especially applicable in the twin phases of moral instruction and moral training. The difficulties inherent both in the content of the course and in the normal reactions of youth to ethical teachings are many; but they are not at all insurmountable as may be noted below:

Public school instruction in morals involves a knowledge content much of which is already known to pupils intuitively.[1] There is required the same kind

[1] Instinct may be defined in a general way as the knowledge and intellectual capacity possessed by animals without its ever having been learned or developed through experience,—an ability to "react" to situations which represents inherited tendencies. Intuition on the other hand involves a nearly automatic and highly efficient use of knowledge which has been acquired; but this acquisition has been more or less unconscious, and wholly apart from formal instruction. Education should avail itself of both instinct and intuition; and it should seek to clarify and enlarge upon, and to give suitable means of expression for them.

of skilled instruction as found necessary in connection with the "Introductory Discussions" of the cycle of elementary science teaching (p. 118). Under guidance of the instructor the knowledge of individual pupils concerning moral standards is assembled, clarified, and by means of contributions of the instructor organized into a well-defined class consciousness so that what was before vague, scattered, and unusable information now becomes available for specific applications in life situations. Right motives for its use, too, are furnished. It is to be emphasized in this connection that whatever to pupils savors of "pious talk," or of "preaching," is a hindrance to and may defeat the instructional ends.

In public schools the teaching of morals must be largely done indirectly. Nowhere can the teacher safely assume to be a final authority and undertake to override dissenting views by force of will or power of position. It is the instructor's province to render assistance to pupils so that they themselves arrive at valid conclusions by expeditious courses of reasoning. It is the pupil himself, however, who must reach these conclusions. There is a marked similarity in this to the second stage of the teaching cycle in elementary science. Use of wisely chosen exercises recalls first-hand information gained in life's experiences as *facts of observation.* Through relationships *as inferences* established among these facts, conclusions are eventually reached for guidance in conduct. Formulating and

suitably phrasing these conclusions much after the manner of a laboratory "write-up," recasting them as necessary in order to make them "fit the facts" of human experience and of life conditions, completes the instructional phase of moral education. The application of these conclusions to personal life experiences characterizes a *period of moral training* whose aim is character formation.

As illustration of a teaching "cycle" specifically adapted to moral education, embracing both the instructional and the applied or training phases, there is given here with brief comments the outline of a lesson on the "Rule of Life" successfully employed by another,[2] and well adapted to the specific ends set forth above.

INTRODUCTORY DISCUSSION

Let it be required that two points some distance apart on the blackboard shall be connected by a straight line. Let efforts to do this be made at first freehand, and then by use of a foot-rule or yardstick *as a guide in making the desired line.*

Definition of a straight line. Comments on usefulness to mechanics of a carpenter's square (a) in drawing straight lines; (b) for accuracy in measurements. Definition for a rule (a) as a tool used by mechanics;

[2] Dr. A. W. Norton (Appendix, p. 286.)

(b) as found in books on games, etiquette, parliamentary procedure, etc.

Purpose of rules for use in life affairs such as in business matters, in social behavior, or conduct in general. The shortest rule of conduct ever heard. ("Do right.") Where first heard and employed? Where else? Occasion for its use in school, and for how much of the time. Use of it in control of one's speech, and of one's thoughts.

Results of use of the foot-rule or yardstick as an aid in drawing straight lines if held in one hand while drawing, *and merely looked at from time to time.* Distinction as to conduct between a "crook," and a straight-forward man. One explanation for the difference. Distinction between laws in civil life and in social customs. Distinctions (a) between "moral laws" and civil statutes; (b) between the "laws of nature," and "laws of science," and "moral laws." Purpose of all rules and regulations in connection with school life whether for classroom, laboratory, or the school grounds. When changed, and why?

Number of rules necessary when living the right kind of lives. Number of rules necessary in school life. Why so many regulations? Danger in having too many rules.

EXERCISES FOR THE WRITE-UP PERIOD

1. In geometry a straight line is sometimes known as a *right line.* How are such lines made?

2. What tool is employed by masons to determine if a wall is vertical? What meaning has the term upright when applied to a man? By what rule is his uprightness to be measured?

3. Recall what is meant by a "crook". Why so named? How may such persons at the same time be law abiding citizens? In a general way what is it to be a criminal whether convicted and punished or not?

4. How is it that those who do right have no need to fear the law, and may safely remain ignorant of its exact terms?

5. Name some penalties for transgressions (a) of civil law; (b) of moral law.

6. Where many rules are laid down for the various activities of school and home life, what is taken for granted concerning permission or prohibition of whatever is not mentioned?

7. Why in school ought there to be no need to "change seats" because of whispering or other disorder? What force has the plea "He got me to do it"?

8. Name some results in affairs of men if for the rule "Do right" there was substituted "Do whatever you please."

PERIOD OF APPLICATION AS A TRAINING IN MORALS

[Pertinent queries at opportune times, generally as suggestions quietly made and as a purely personal matter: Have you your "rule" with you to-day? What rule should be used here? (Applicable equally well to

cases of behavior, speech, or thought.) When are you going to begin use of your rule? You do not seem to be making use of your rule—why not? Why plan for yourself a crooked life? How only is a straightforward life possible?]

For those who are stubborn or who are possessed of perverted moral views, and especially in cases of the smaller misdemeanors requiring personal interviews in the "principal's office," there is necessary: (a) a full and frank understanding, *and a statement in writing,* of the main facts involved in the situation; (b) opportunity for the pupil to convince the teacher that his conduct (or his speech, or his line of thinking) is straight "according to rule," and "on the square"; (c) fullest freedom accorded a pupil for presentation of his case free of interference or argument by the teacher.[3]

Attention is to be called to the fact that the standards of children and youth lack the distinctions and definiteness which are the natural results of more mature years. To "play fair" in all things may be a wholly satisfying demand to them, and one which may not discern or take under consideration any aspects for good or ill beyond the immediate issues involved. Then, too, the forcefulness of the old adage that "Example is better than precept" is manifest in the ready discernment of, and the biting comments by pupils upon,

[3] Several other lessons of similar purpose, but obviously out of place here, are placed in the Appendix.

any delinquencies of teachers whether fancied or real. Pupils are keen observers of conduct by teachers, better observers in matters of conduct than they are, it may be, in studies of experiments. It behooves a teacher to be fair and just in all relationships, outspoken for what is decent and right, and at no time petty, mean, or malicious. No demand on teachers is more unrelenting and insistent than that they not only do what is right, but that to the extent of their influence they "make things right."

Summary

1. Clearness of perception of purpose which should dominate educational effort.
2. Characteristics of growth during school life into manhood and womanhood.
   (a) School work a training process to these ends.
   (b) Relationship of conduct and character.
3. Difficulties involved in a training for character development.
   (a) Relationship of what an individual knows to codes of ethics and rules of conduct.
   (b) Self-protection by teachers against discouragement in efforts for moral training.
4. Equality of opportunity for all pupils in training towards manhood and womanhood.
   (a) The task of teachers in every succeeding generation.
   (b) Educational conditions for an enduring civilization.
   (c) School effort which defeats itself.

5. Education defined in terms of character development.
   (a) Changes in characteristics normal to advance in age.
   (b) Hesitancy in right doing which alone is justifiable.
   (c) An undesirable citizenship despite brilliant intellectual attainments.
6. Importance of repetition as "drills" in matters of conduct.
   Relationship of this to a teaching "cycle" in elementary science instruction.
7. Similarity of procedure in elementary science and in moral education.
8. The knowledge content in moral instruction.
   (a) Value of instinct and of intuition in the process.
   (b) Procedure followed. Course to be avoided.
9. Suggestion as a factor in moral instruction.
   (a) The teacher as an authority in morals.
   (b) Observations and inferences in moral instruction.
10. What constitutes training in morals as distinguished from instruction.
11. Illustrative lesson in moral training—"Do Right."
   (a) Need of a rule as guide to conduct in life efforts.
   (b) Rules of conduct *to be used*, not formulated merely.
   (c) Number of rules of conduct necessary.
   (d) "Exercises" for the write-up period.
12. Moral training as an application of moral instruction. Features of school discipline possible for individual pupils.

CHAPTER XVII

THE STATUS OF HIGH SCHOOL SCIENCE, WITH ESPECIAL REFERENCE TO THE DEVELOPMENT OF HIGH SCHOOLS

In 1860 there were perhaps forty high schools in the country; [1] in 1870, seventy of them; [2] in 1890, two thousand five hundred; in 1910, twelve thousand; and now (1925), possibly eighteen thousand. From 1890 there has been an average increase in the number of high schools of more than one for every calendar day —*a new high school a day for thirty five years.* The number of high school pupils in 1890 reported was 202,000; in 1918, the number was 1,645,000.[2] In this same connection it is noted, too, that of these high schools about two-thirds of them have an enrollment each of 75 pupils or less, while but 5% of them enroll over 500 pupils each. Thus the "high school problem" is essentially one of the smaller rather than of the very large high schools.

The growth in high school attendance in this country in the past fifty years is a marvel in educational history difficult of full comprehension by those actively participating in its realization. Promoted by legal

[1] John W. Woodhull, *School Science and Mathematics* (IX: 267).
[2] Bulletin 19 (1920), Bureau of Education, Washington, D. C.

requirements, and fostered by the spirit and genius of our form of government and the economic prosperity of the nation, a generally higher educational level has been demanded by a 20th century civilization. It would seem that almost in a single generation all American boys and girls began going to high school. A high school graduation now counts as the minimum of schooling to be furnished at public expense to fit for citizenship.

To provide buildings and equipment to care for these throngs who crowded into the high schools, communities taxed themselves to the limit and imposed taxation burdens upon generations then unborn. School administration officials throughout this period were as a class kept in a state of mind bordering on frenzy to care suitably for these boys and girls who clamored for admission and instruction. There was need to frame and remake curricula again and again to meet the wide range of desires in different fields of learning. All sorts of substitutions and electives were provided to give flexibility to these high school courses, and to provide such an "appeal" to pupils that all would remain in school to graduate. A curriculum was necessary which should make it possible to move onward with machine-like certainty these masses of boys and girls that they in turn might make room for others. Local pride in a big high school crowded to the limit, together with a more or less pardonable pride on the part of superintendents and principals concerned over

their professional standing and their advancement in the affairs of school administration, likewise entered in as factors in a hectic period of school development.

With costs of the public schools reaching appalling sums, a system of "cost-accounting" per pupil brought notably to light various facts in connection with the teaching of science subjects in contrast with other branches in a high school curriculum. Science teachers demanded for the successful teaching of their subjects what was considered an undue allotment of their own time and that of their pupils—seven hours per week at least in classroom and laboratory rather than five. Then small groups only could be handled advantageously thus multiplying sections in any one course, and keeping down the numbers of pupils per week in the classes of a science teacher. Fewer classes per day could be assigned a science teacher owing to time required to prepare for laboratory exercises, and then to clear away after the experiments. Then, too, the expense of installation and upkeep for science teaching presented conditions where without doubt "money talks."

That the science instructor might carry the same teaching load as others on the teaching staff, laboratory work had to be cut to a minimum or eliminated. Texts were sought which in an interesting and more or less instructive manner told of the marvels of science, and the usefulness of its applications. Substitutions and "electives" permitted students to go

through high school with no science whatever, thus solving happily the problems of administration centering in the science work. To lighten the load of overtaxed science teachers in the smaller high schools especially, science subjects were parcelled out one subject here and another there to instructors in other fields of high school work, and this without particular regard at times to any preparation or fitness for such science teaching. The immediate end sought was to equalize teaching loads. The teacher of French might get a class in botany though her sole knowledge of the latter subject was perchance a five hour course in college taken as a "group requirement." The physics might go to the coach in athletics to give him something to do when not busy with training his teams, or otherwise employed in connection with athletics. His tenure of position, his salary, and his success or failure in the field of secondary education would be in athletics and not in science. General science not infrequently has been turned over to any one who had time for it, and who did not protest sufficiently an unfitness for teaching it.

That such conditions affecting the integrity and very existence of suitable science instruction in high schools may not as yet have become the rule in that two-thirds of the high schools of the country enrolling 75 pupils or less each, is not to any notable extent to be credited to any group-consciousness on the part of science teachers, and of organizations of science teachers. That it

may become even more common in spite of efforts by science workers is very possible. School administrators will continue to point to a high-cost-per-pupil-instructed in science as compared with cost of instruction in other high school subjects. They will demand evidence *other than claims made by science teachers* of the superior educational values from science instruction. Thus it will be no easy matter to regain and retain the old-time prominence of science in high school curricula, and in the minds of high school pupils and of school administrators. "Surveys" of teaching efficiency in the sciences must compare favorably with results of instruction in other branches.

And in this connection, too, it will be found of little purpose to undertake to point out to young men and young women who in college courses show marked native aptitude and tastes for teaching, and whose scholastic attainments and aspirations single them out as promising teacher-candidates, their need for teacher-training, and any call to them for service as science teachers in secondary schools. From their own observations and experiences as high school pupils they are well acquainted with conditions likely to confront them when seeking positions as high school science teachers.

Educators generally, and science teachers in particular, have for years deplored the passing from schools of a spirit among pupils which was in evidence to a marked degree in the earlier days of science teaching. In the old-time academies of the eastern states, and

into the first of the period of development of high schools, the pupils in school looked forward to a time when older grown they, too, might be in the class in natural philosophy and be taught concerning the things of science.

It is true that college classrooms and laboratories to-day are so congested by students as to make it difficult to care suitably for them by reason of their numbers. In an all too large degree, however, this is but a result of the group requirements for college graduation, and is in no sense evidence of any thirst for knowledge in the realm of science. Any acquisition of scientific attitudes of mind, and of scientific procedure in thought processes in those surviving such required freshmen courses in science, are not notably in evidence. It is true that in this day and age people generally are acquainted with the uses of electrical devices for their comfort and welfare. They spend much time in running about the world on wheels, and supposedly know something of conditions necessary that these wheels may be kept running. They may travel by airplane or submarine, and get information and enjoyment by radio, but all this in no way establishes the fact that use of these achievements in applied science arouses any spirit of inquiry, or stimulates in any sufficient degree for educational valuation intellectual growth and mental attainments.

In connection with the status of science in the high schools of to-day is one dominant need—the need to

regain and better the former standing of science subjects in high schools as part of a connected line of well-related and properly organized science instruction, and to have this place taken for granted even as in the case of languages, mathematics and social sciences. Elsewhere throughout this book there has been stressed the importance in education of science instruction when given by those who have both "vision" and fitness to instruct. All such possibilities may be to little purpose, however, by reason of conditions over which science teachers, and those interested in the promotion of education by means of science studies, may wholly lack all control. In contrast with discussions of the dismemberment of science work in high schools, its lack of continuity and proper sequence and its subordination to other fields of major interest to high school teachers, it is of little moment to become wrought up over whether much or little notebook work shall be required of pupils in science classes; and whether or not much in the way of quantitative experiments shall be demanded in a high school course in physics.

In this same connection, too, and of large moment as a factor in the situation, is the certification of science teachers. As licenses to engage in teaching, these certificates are granted by teacher-training institutions and by public school officials under authority of law. Wide variations in requirements for certification exist in different states, and laws governing issuance of cer-

tificates to teachers are ever being changed in all the states. In general, however, certificates are granted for Elementary Schools and for High Schools rather than for certain lines of work such as science, English, or mathematics. The holder of a high school certificate is then by virtue of such certification entitled to engage in the teaching of any and all of the high school branches however unprepared in subject matter. That science teaching suffers and may be made a farce, need not be argued. While superintendents rest satisfied with this grouping of teacher's certificates by reason of their particular interests in the grades below high school, and while principals of the large high schools can control the situation by reason of special teachers for the several science branches, it is in that two-thirds group of the high schools—those of the small enrollments—where science teaching experiences the harm from lack of qualifications on the part of teachers other than such as entitle the holder of a certificate to teach any high school subject.

Colleges and universities, getting in their student body the product of instruction given in high schools, can scarcely remain uninterested spectators of such situations so far as science instruction goes. It is not so much a question of whether or not pupils come from high schools with or without certain preparatory courses in science subjects. It is a question of whether or not they come fitted to undertake beginning courses in college science by reason of suitable training in high

school science courses. It is not the subject matter of elementary phases of science, but whether these students have the attitude and spirit wherewith to catch step and lay hold upon instruction in science courses supposedly suited to college freshmen.

There would be little purpose here to indulge in statistics concerning the extent to which conditions prevail whose existence imperil the possibilities of science in secondary schools. A mass of data has been gathered by independent investigators whose general purpose when summed up was to learn "What is the matter with science?" Much of this material is to be found in such publications as *School Science and Mathematics*. Much lies hidden away in findings on which have been based various "Theses" for advanced scholastic degrees, and none of it would be in place here. But in calling attention to these very general and more or less unsubstantiated claims concerning conditions which affect the educational values of science in high schools, both in the present and for the future, there is no intention to be unduly pessimistic. The authors are simply mindful of the famous remark attributed to Mark Twain with reference to the weather that "A great deal is said about it, but not much done." For certainly not much has been done by science teachers themselves to meet and master the problem of control over conditions vitally affecting secondary school science as an accompaniment of high school development in the past half century. It is

their mind that not to develop a class consciousness among those zealous in the cause of science instruction in the public schools, but instead to give over time and effort to heated controversies with other science teachers who may not agree exactly with one's own views, is to fritter away a heritage of educational values inherent in the matter and method of high school science when properly taught.

As a closing word regarding the status of science teaching in high schools, it is in place to note certain requirements in the training of science teachers in Normal Schools and Teachers Colleges. There still persists in this general training for high school teachers what to those engaged in the field of secondary school science is wholly indefensible. To begin work in Education with a course in the history of educational systems, whether of earlier or later periods, is not good pedagogy. It is the spirit of science teaching that classes of beginners be started in any new field with the organization and extension of what is already more or less well known to them, and preferably what is of their immediate experiences. Surely in this connection there would be any sufficient number of problems confronting one who seeks to enter upon teaching service. Included in such would be topics of special instructional difficulty, as well as controls of teaching situations.

The authors do not have in mind in this connection the work done in graduate schools of education, nor

necessarily any courses undertaken by teachers of considerable experience. For such students an historical survey suitably provides a background into which may be fitted various advanced courses in education. But if within four years of college attendance (120 college hours) a student must make a major and minor in academic courses in science; must meet requirements in educational psychology, and in theory and principles of education; must take courses in methods, both general and special; and must do enough of practice teaching to familiarize a beginner with difficulties inherent in teaching as an art, then after having met various "group requirements" there is little opportunity for anything else. Teacher preparation for high school sciences assumes in no inconsiderable measure the aspects of vocational training. The authors conceive it true, whether in science or in education, that a working fund of concrete knowledge—the "known" as distinguished from the "unknown"—is a necessary foundation for theories in education even as in science, just as they are necessary for the beliefs and opinions cherished by men in all relationships of life. The central feature of teacher-training so far as science teachers are concerned, and apart from a mastery of subject matter indispensable to any teaching undertaken, are its demands that in education courses for science teachers a laboratory basis is required just as truly as in the mastery of any of the natural sciences. They are mindful, too, that the day is remote when in the

smaller high schools of the country there can be maintained the high teaching proficiency in science to be desired if teacher-certification of the kind noted above continues, and the dismemberment of science in such schools goes on.

Summary

1. Growth in the number and enrollments in high schools of the United States since 1870.
   Distribution of high school attendance.
2. Factors in the development of the high school, of the country affecting the sciences in these schools:
   I. "Electives," and alternative courses for graduation.
   II. Cost-per-pupil for instruction in science.
   III. Distribution of teaching "load." Dismemberment of the science.
3. Effect on teacher-supply of present-day status of science in high schools.
4. Misconceptions based upon congested conditions of college laboratories.
5. Certification of high school science teachers.
   Basis for judging the worth and fitness of candidates for science teaching.
   Conditions of certification essential for betterment.
6. Requirements of teacher-training institutions in education courses for all secondary school teachers. Effect upon preparation to teach sciences in high schools.

PART III

CHAPTER XVIII

SCIENCE TEACHING BELOW THE HIGH SCHOOL AS NATURE STUDIES

College courses in science may very properly have as their aim an effective presentation of knowledge in accordance with the theories of the science concerned. The more detailed the facts, and the more exact the generalizations based on these facts, the better. The college instructor assumes on the part of his students both maturity of mind, and a purpose to master that which is presented in classroom and laboratory. A subjective treatment of topics dominates the teaching situation.

On the other hand, the amount of subject matter in nature study is small. Its treatment is objective. Theory is incidental, or is wholly unwarranted in the teaching procedure. The teaching "problem" is the child mind rather than knowledge organized in accordance with scientific theory. Teaching successes and teaching failures in nature studies should be considered as fundamentally a matter of teaching aptitude, and of versatility in knowledge of child nature and childhood experiences. First-hand knowledge of the phenomena of the natural world on the part of a teacher,

and an ability to interpret these experiences in a vocabulary adapted to those under instruction, are dominant factors in successful nature teaching. It is true here as in teaching generally, of course, that one cannot teach what he himself does not know. But let it be strongly insisted upon that instruction in nature study must center in and be grouped about objects and phenomena of the natural world *as these are being observed.* Books about nature's forms and phenomena *may be used by the instructor* for inspiration, and for definite and detailed information. For such pupils as may be able to read intelligently, books may be used as supplementary sources of information and of interpretation. However, nature study as an elementary school subject *must ever be a first-hand study of nature's works and ways* in contrast with attempts to center these studies in what someone has said in books. Pictures, diagrams, mounted specimens and the like, however serviceable in nature teachings, *are substitutes only.* Word descriptions by the teacher or taken from books *are valuable to the degree in which by comparison with known and familiar objects they convey definite concepts.*

In aptitude, in professional preparation, and in successful experience the teacher of nature study must be the peer of any in the teaching force. It is quite to the point to insist that apart from a relatively few exceptional cases of notable natural aptitude in teaching, those become efficient teachers only who have had

special training in the choice, adaptation, and objective presentation for instructional ends of material suited for nature studies. And this preparation, too, must not ignore the common limitations in number and size of classes, and lack of supplies and room furnishings common to instruction in public school service. The methods of the kindergarten project themselves into presentations of nature lessons. Success in nature teaching, so it must be insisted upon, on the one hand involves less of knowledge in scientific fact and theory and applications, but on the other hand more of teaching principles applicable to the educational ends to be attained. The procedure followed in teaching must be of a character reasonably certain to assure the attainment of these ends.

In the rise and fall of the nature study movement in this country a generation or more ago is to be seen an excellent illustration of the difficulty of maintaining in the public schools any subject the educational values of which depend so largely as does nature study upon superior qualifications of the teachers employed, and upon teaching excellence through ripened experience. Or, in other words, a school subject in which the use of textbooks is largely or wholly barred must by its very nature demand of teachers large natural aptitude and a suitable professional preparation.

To many teachers of the present generation, nature study so far as the public schools are concerned may be scarcely more than a name. Yet any careful exam-

ination of the literature of nature study during the last quarter of the past century and the first decade of the twentieth century arouses wonderment by reason of its volume and its pedagogical worth.

Then, too, one does not need to look farther than through the pages of such a book as Scott's *Nature Study*[1] to come to a realizing sense of the fact that the difficulty of the course lies not in its subject matter, nor in any large degree in the selection and organization of its material, but instead almost completely in its manner of presentation. It may be that there are nature enthusiasts who by reason of experience and tastes are so imbued with an enthusiasm for the natural surroundings of life that as teachers they score a great success even when they have not attended a training school. But for the rank and file of teachers, from kindergarten through primary and intermediate grades, the problem of preparation for nature study teaching is primarily a problem of insight into its spirit and purpose rather than of serious concern over subject matter.

It is not the purpose of this chapter to enter upon any discussion of what this spirit is. Such books as that referred to above serve this purpose well, whether recent publications or not. But rather it is desired to incorporate in this connection some of the lessons used with classes of prospective teachers of nature study illustrative of an organization of lesson material to give help to busy grade teachers struggling with the prob-

[1] *Nature Study:* C. B. Scott (1900). D. C. Heath & Co.

lems of making choices of material for use. Naturally such lessons must lend themselves to ready modification in order to be usable as needed with pupils either more advanced than the fourth and fifth grades, or younger. Each of these lessons is presented as a series of related topics, but it does not necessarily follow that the teacher may not take paragraphs from any one lesson, or may not arrange and rearrange the order of topics as teaching conditions warrant. Back of all other purposes, there has been in mind that the greatest service to be given in any such arrangement centers in its provision for objective instruction in relation to simple thought-provoking natural phenomena. Such studies in spirit and in procedure are not unlike, and may in fact be, a series of laboratory exercises.

It is understood, of course, that use of books by the pupils in nature studies is largely if not wholly out of the question. Information gained by the children must be from first-hand observation of whatever object or phenomenon constitutes the central feature of the lessons for the day. Such observation and inquiry directed at all times by the teacher necessarily yields knowledge fragmentary and not fully comprehended. This necessitates at all times such instruction on the part of the teacher in connecting and clarifying what the children themselves learn as observers as shall make the product complete within the teaching limitations. Such information furnished by the teacher while in accord with what is to be found in books must

if it is to yield the desired results be information gained in part at least by the teacher himself from nature's own pages.

No attempt is made to develop these lessons in detail. Teaching situations are so dependent upon teacher and pupils as "human factors," and upon times and conditions of teaching, as to render this apparently unnecessary. Then, too, books of this kind are already available for teachers who feel the need of this guidance.[2] That there is little of inspiration in any mere outline of selected items of subject matter is fully appreciated. But so numerous are the demands made upon the time and strength of teachers apart from any need to make suitable selections of teaching material and to organize it for teaching purposes, that it is well to have at hand some such ready-prepared nature studies as those which follow. Out of a teacher's own experiences in due time should come other lessons more or less original in form and content, and suited to the needs and tastes of the individual teacher. Modifications of any lesson here given by the omission of any particular items, or of whole paragraphs, in order better to adapt the lessons to particular teaching conditions, is easily done as needed.[3] The language employed in these lessons is of course the teacher's. It is subject to such modifications when used with children as teaching conditions demand.

[2] *Nature Study:* Crawford (and others). (Hinds, Noble & Eldredge.)

[3] See other Lessons in Appendix D.

I. BODY LESSONS [4]

The Hand

1. Which part of the arm as a whole is the hand? What name is given the part where the hand joins the forearm?

2. After moving the fingers in all possible directions, state what is true (a) of the freedom and variety in their movements; (b) of the number of muscles required for these movements.

3. While the left wrist is held in a close grasp by the right hand, observe any movements through the wrist as the fingers of the left hand are moved about. Explain what is seen and felt.

Take firm hold of the forearm just below the elbow; move the fingers freely, and explain any movements noted in the arm.

What purposes are served by having these muscles so far away from the parts moved by them?

4. By what other means than the use of many muscles is variety in movements of the hand secured? Count the bones (a) in each finger, and in the thumb; (b) across the thick part of the hand.

What purposes are served (a) by binding together the bones forming the palm of the hand; (b) by having the thumb so loosely connected? What advantage re-

[4] By permission from *Laboratory Lessons in General Science:* Brownell: (The Macmillan Company.) Lessons on Mouth and Eyes will be found in Appendix D.

sults from having one less bone in the thumb than in a finger?

5. What name is given to the inner side of the thick part of the hand? What is the name given to the union of any two bones? What special name is given the places where the fingers are joined to the hand? What kind of motion only is possible in the joints of a finger? What purpose is served by these limitations in the freedom of finger movements?

6. State very definitely the location of the nail on a finger. Describe the general shape of the finger nails, and any markings on them. What is peculiar in the growth of the nails? What are their uses? What care should be given them?

7. Describe the appearance of the skin in the palm of the hand. What variations are noted in its thickness? Account for the deep markings in the palm of the hand.

8. Name several important uses of the hand. State what difficulties would be experienced by a person who had lost both hands. Because of lack of hands how must animals feed themselves? What is true in a general way of the adaptation of the hand for ministering to the needs of man? Name several uses of the hand that illustrates the skill to which it may attain. By what means are hands and fingers made to act in obedience to the mind?

II. EARTH FORMS [5]

1. Study of a Stream

1. Mention by name (or locate otherwise) the nearest creek, brook, or river to the school building. Have you been to it? How far is it from the school (a) by highway; (b) by most direct route? Are there fish in its waters? If so, what kinds? If not, why not?

2. What is true of the rate of its current at different places? In general is the current swift or sluggish? How proceed quite accurately to determine just how swift it is at any point? Why not swifter? Why the direction it flows rather than some other direction?

3. Describe the course of the stream so far as known to you, telling whence it comes, the general direction of its flow, and what becomes of its waters. Upon what largely does the volume of its waters depend? For how long time will this stream be likely to continue to flow?

4. To what distances up and down have you followed the stream? Which is the right bank (a) of this stream; (b) of any stream? Describe in a general way the character of country through which it flows as you know it, whether level, hilly, broken, mountainous.

Recall any relation between (a) character of the banks of the stream and the rate of current; (b) character of country and steepness of banks. What differ-

[5] By permission from *Laboratory Lessons in General Science:* Brownell. (The Macmillan Company.)

ences were noted in the bed of the stream at different places? How account for this? What explanation for any swift and broken current ("rapids")?

What significance had places of comparatively still water? What was noted of the widths of the stream at different points? What relation had this to (a) the depths at such places; (b) the character of the banks?

5. Of how much use in navigation is this stream? Why so? Its usefulness for manufacturing (if any), and why so? Name other respects in which it is useful.

2. Valleys, and Surface Erosion by Water

1. From observations made of some gentle slope by field, roadside, railway cutting or earth pile where the earth is bare and subject to wash by rains, what relation is apparent between steepness of slope and (a) crookedness of any channels cut by the flowing surface waters; (b) depths of the cuts.

Offer an explanation of (a) crooks and turns in these channels rather than being straight; (b) greater depths of some cuts than others.

2. Distinguish between a main channel, and any tributaries of it. Why any tributaries? What is meant by a "divide" between adjacent channels?

3. Make a sketch of some imaginary stream and its tributaries, and by appropriate lettering locate thereon (a) main channel; (b) any tributary; (c) the mouth

of the main stream; (d) its source; (e) a divide between two tributaries.

Enclose by a continuous dotted line on the sketch what is included in the "water-shed" of the system. What is the meaning of (a) river basin; (b) river system?

4. How much is included within the limits of a valley? How many slopes to it? How account for lack of streams in so many of the smaller valleys? What various names are given to very small valley forms? How account for their never having become larger?

Account for the existence of valleys in general. How then may hills be often accounted for? Where hills of considerable height exist what may be supposed true of the nature of the material of which they are made up?

5. Where flowing water makes cuts in the earth (a) upon what factors does the rate of cutting depend; (b) which parts of the surface are more readily carried away?

What significance in the muddiness of some surface waters? Under what conditions will this muddy water become clear? Why is it that streams made up of surface waters from the hillsides in some parts of the country are quite clear, and free from sediment? What of the fertility of those hillsides?

What largely becomes of the soil washed off into streams? What is a result of the continuance of this

(a) in fertility of farm lands; (b) in surface level of the country?

III. SOIL STUDIES

Material: Sand; clay; loam (field soil); specimens (when possible) of granite, feldspar, quartz; test tubes; funnels; student lamp chimneys.

1. (Exp.) Fill a test tube one-half full of coarse sand. Pour in enough water to nearly fill the tube. Account for any bubbles rising through the water, and where they come from.

2. (Exp.) Using a magnifying glass note the relative sizes of sand and clay particles.

Story of the origin of sand and clay. What silt is.

3. (Exp.) Shake together well a half-inch each of clay and coarse sand in a test tube, after nearly filling the tube with water. Note the arrangement of particles after subsidence.

Discuss (a) transportation and sorting of rock particles by water; (b) depths of soil in different regions.

Story of slate, and of shale. Odor when wet.

4. Varieties of soils—clay soil (60% or more clay particles); sandy soil (75% or more of sand); loam (mixture in various proportions of sand, clay and silt).

Behavior of clay when wet, and then when dried.

Brick-making. Pottery—glazed and unglazed.

5. (Exp.) Drainage ("run-off") of 50 cc. of water poured upon a tablespoonful each of clay and of sand on filter paper in two funnels which are set in test tubes in a test tube rack.

Adhesion of water film to finger.

Amount of exposed surface of crayon as it is broken into smaller and smaller pieces.

Explanation of different "run-off" from sand and from clay.

6. (Exp.) Heating of test tube of dry soil powdered to dust. (Be sure before heating to have inside walls of tube wiped clean.)

Persistence of water film on soil particles, even in spite of evaporation.

7. (Exp.) Over the small ends of three student lamp chimneys tie double thicknesses of cheese-cloth. Fill each one-third full using sand in one chimney, clay in another, and well pulverized loam in the third. Support these chimneys upright in a dish of water, the cloth-covered end down, and leave for several days. Note the relative rates of rise of water into the soil spaces by adhesion of a water film to the soil particles (capillary phenomenon), and the extreme heights to which the water level is raised.

Explain any rise at all, and why to a greater height in some cases than others.

Story of how plant roots take in (a) soil water; (b) air. Effect on plant growth (a) of water-soaked soil; (b) of a soil bed for seed germination and growth when not well pulverized and kept mellow by cultivation.

Explanation of failure of water-soaked (poorly drained) soils to warm up sufficiently for growth of vegetation.

References[6]:—Bigelow: pp. 28-37, 87, 99. Snyder: pp. 85-109. Comstock: pp. 842-849.

IV. WATER IN RELATION TO PLANT AND ANIMAL LIFE[7]

1. Properties of Water

1. Which of all the things needed to keep us alive causes suffering most quickly when withheld? Which next? What is the price we need to pay ordinarily for either? How do you account for this?

2. Taste water from different glasses, one glass having in it salt, another sugar, another vinegar. Then taste of pure water. What property of pure water is shown?

3. Smell ammonia water cautiously; then pure water. Name another property of pure water.

4. Look at a pencil through glass. Put the pencil in water, and look at it through water. What other property of water is shown? Explain the muddy appearance of some rivers.

5. Pour water into dishes of different shapes, and state the form taken by the water in every case. Why is this? Make a distinction between solid and liquid states of matter.

[6] *Applied Biology:* Bigelow. (The Macmillan Company.) *First Year Science:* Snyder. (Allyn and Bacon.) *Handbook of Nature Study:* Comstock. (Comstock Publishing Company.)

[7] By permission from *Laboratory Lessons in General Science:* Brownell. (The Macmillan Company.)

2. Solution

1. Make crayon marks on the blackboard, or lead pencil marks on paper. Why does an attempt to jar or shake these off not succeed?

2. Dip a finger into water. Explain why it comes out wet.

3. Let a stream of water from some height fall into a jar of water. Account for the bubbles of air in the jar.

4. Lower into water a rough stone. Why do not all the air bubbles on the surface of the stone rise to the liquid surface?

5. Drop a lump of salt into the water. State what change occurs in it. Where is the salt now? What would be true of any effort to get a drop of water from any part of the vessel that did not have salt in it?

By what are the particles of salt and water held together? What apparently must be true of the size of the salt particles?

6. Evaporate some of the salt solution to dryness. Taste any solid left. What is it? Let the rest of the liquid stand in a covered dish till next day and see if any of the salt settles to the bottom. If not, why not? Try to filter out the salt. What is here taught of the size of the particles?

7. Stir a little earth into a tumbler of water, and let

it stand. Explain the result. Why does cream rise on milk?

8. Heat gently some water in a test tube. Where does the air that collects on the sides of the tube come from? (Bubbles of steam if formed could not persist in the water below boiling temperature.) Explain how this air was kept in the water.

9. Lay a blotter down upon a drop of ink. What is done to the ink by the blotter? How can this be? Since we say that water dissolves air, why not say that the ink dissolved the blotter, or the blotter dissolved the ink?

3. Nourishment of Plants and Animals

1. Nature of the sap of plants. Whence it comes. Relation of fineness of soil to its water content. Chief purpose of roots for plants.

2. Disposal of sap water to make room for more nourishment. "Bleeding" of injured trees. Wilting of plants.

3. Purpose of digestion of our food. How it is that teeth aid digestion. Why it is that proper cooking of food is an aid in digestion. One purpose of circulation of blood. Proportion of water in blood.

4. Water in the Atmosphere

1. What change occurs in the quantity of water (a) when a little is left in an open dish exposed to the air

for some time; (b) when a wet piece of cloth is hung up exposed to the air? After some water has been boiled for a time in an open dish, what is true of the quantity of it? In all these cases what becomes of the water?

At what temperatures does this vaporization of water go on most rapidly? Name other conditions that favor a rapid vaporization of water from the earth's surface. Name several sources whence the supply of moisture in the air is maintained. Whence comes the heat?

2. Over the mouth of a test tube in which water is boiling hold an inverted wide-mouthed bottle whose sides are dry and cool. Describe what takes place. What relation is there between these processes of vaporization and condensation? What causes condensation of the moisture present in the atmosphere?

3. How is it that in some regions of earth a sudden and extreme fall in temperature may cause no precipitation either of rain or snow? What is true of the general character of a region, and its fitness for habitation, where the atmosphere is commonly destitute of moisture? In regions that are far away from large bodies of water, how is the supply of atmospheric moisture sufficient for an ample rain-fall to be accounted for?

4. Describe the difference in conditions resulting in formation (a) of dew and rain; (b) of white frost and snow; (c) of fog and cloud.

V. COMBUSTION [8]

1. Put a long narrow lamp chimney down over a short lighted candle set in a dish containing a little water. Repeat several times, and state what occurs. Explain.

Repeat these tests, having a partition of tin reaching down through the chimney at one side of the burning candle. Hold an extinguished match that is still smoking at the top of the chimney first on one side of the tin and then on the other. Observe the smoke. Infer the significance of the behavior of the smoke.

2. Let the teacher carefully melt a little potassium chlorate in a test tube, and then heat it till it bubbles. Observe the results as bits of match sticks are dropped into the hot liquid.[9]

The gas *oxygen* is set free from the chlorate as result of a chemical change, and the union of the oxygen with the wood is another chemical change.

Infer concerning (a) the nature of combustion; (b) the composition of air that supports combustion of the candle.

The rusting of iron and the decay of vegetation are illustrations of oxidation. Why are these not commonly considered cases of combustion?

[8] By permission from *Laboratory Lessons in General Science:* Brownell. (The Macmillan Company).

[9] It is a wise precaution to fold a strip of paper into several thicknesses and wrap it about the upper end of the test tube as a holder. If the tube be heated nearly to its full length at first, there will be less likelihood of breaking it as water from the crystals of the chlorate is driven off.

3. Into an evaporating dish, put a teaspoonful of gasoline. Bring to it a lighted splinter, and observe.

Half fill another dish with kerosene, and test in like manner. Pour out all but a little of the kerosene, and warm slowly what is left, testing frequently with a lighted splinter held just above the dish. What is necessary for a flame from kerosene?

4. Light a candle. After a moment extinguish it, and immediately hold a lighted match just above the wick. Repeat several times, noting whether the wick can be lighted when the flame is some distance from it. Infer how this is made possible, and what the flame of a candle really is. What conditions seem necessary for any flame? Name in order the steps in the ignition, and continued combustion, of a candle.

5. Note the parts of a candle flame distinguished by color, and state their relation to the wick and to one another. Hold in the candle flame just above the wick the wood part of a match, withdrawing it after a moment to observe the positions of the charred parts with reference to parts of the flame. Repeat several times, and infer concerning the interior of the flame.

Press down over the candle flame nearly to the wick a sheet of white paper. Withdraw it before the paper ignites, and observe the form of the charred portion. From several such attempts reach a conclusion as to the interior of the flame.

Describe the parts of a candle flame as to nature

and form. Explain the persistence (a) of the inner cone; (b) of the wick.

6. Put the tip of a blow-pipe into the inner cone of the candle flame, and by repeated trials cause the yellow part of the flame to nearly disappear. Explain.

Hold the inner edge of an evaporating dish in this blow-pipe flame for a moment. Then hold another part of its surface in the candle flame. Observe any deposit on the dish in either case, and infer its nature and source. Explain any variation in amount in the two cases. Give an explanation of the light-giving power of the yellow part of the candle flame.

7. Hold a clean dry bottle mouth down over a burning candle, and look for any moisture (water) on the sides of the bottle. If it be assumed that there is no water in the candle material, how is its appearance in the bottle to be accounted for?

Observe the effect on a lighted splinter when it is put down into the bottle that has just been held over the candle flame. Explain. Set the bottle aside with a cover on it. When it is cold put into it 10 cc. of lime-water, and shake. Any milky appearance of the lime-water is probably due to the presence in the bottle of a gas known as carbon dioxide.

8. Breathe through a glass tube into 5 cc. of lime-water in a test tube till a marked change occurs in the lime-water. Explain its significance. What is indicated concerning processes within the body? Whence is derived (a) the oxygen; (b) the carbon? In what

respects does this oxidation within the body differ from ordinary combustion? What significance has the fact that people in cold weather and in cold climates crave fatty foods? What is the normal temperature of the human body?

9. What are signs of lack of oxygen in the air that we breathe? By what means other than respiration may the air of our rooms be robbed of its oxygen? What provision does nature make to rid the air of carbon dioxide, and to restore oxygen to it?

Summary

1. Objective and subjective aspects of science courses in college and as "nature studies" below the high school.
   (1) The teaching "problem" in nature studies.
   (2) Chief requisite for teaching success. Dominant factors in nature teachings.
   (3) Part played by books in nature study.
   Extent to which book readings, and word descriptions by teacher, are valuable.
   Uses of pictures, diagrams, and mounted specimens.
2. Notable qualifications for success in nature teachings.
   (1) Kind of teaching methods employed.
   (2) Occasion for disappearance of Nature Study from curricula of elementary schools.
   (3) Literature available for teaching nature lessons.
3. Purpose of nature study lessons which follow.
   (1) Use by teacher of books as storehouses of detailed information supplementary to personal observation. Use as guide in manner of teaching procedure.

(2) Advantages of ready-made lessons at all times available for use of teacher. Preparation of original lessons.

4. Outlines of lessons for objective studies:
   (1) Body Lesson—The Hand.
   (2) Earth Forms—Streams, Surface Erosion.
   (3) Soil Studies.
   (4) Water—Its Properties, Solutions, Nourishment of Plants and Animals, Water in the Atmosphere.
   (5) Combustion.

CHAPTER XIX

GENERAL SCIENCE

In general science one of two well-defined general educational aims is likely to dominate the teaching procedure. The more clearly these aims are discerned and differentiated by anyone undertaking to teach general science, the more satisfactory will be the results achieved. Frequently the choice is determined by school authorities, and at times without consultation with teachers. In no small degree choices will be determined by teaching conditions. Also, almost inevitably the day-by-day teachings in general science are colored if not dominated by whatever special preparation has been made by a teacher in this field, and by his natural aptitude with regard to inductive processes of teaching.

That the educational values anticipated from an introduction of general science into the curricula of secondary schools may not have been attained is all too often traceable to the fact that it has been taught by those who lacked special fitness for teaching it. Such results are the sorry experiences alike for all subjects inadequately taught. General science no more than any other subject is a panacea for educational

ills in secondary school instruction, neither is it less than other subjects "fool-proof" in its teaching. In a very large sense *teachers of elementary science must be made.*" "Method" to a very peculiar degree is a dominant factor in teaching general science. Success or failure in it in many cases undoubtedly may be charged against administrations whose choice of teachers has ignored natural fitness and special training. Failures in teaching, too, are more likely to be on account of the mode of instruction than from difficulties in subject matter employed.

But the teaching of general science in many of the smaller high schools is likely to remain in the hands of instructors who for the most part lack adequate preparation for the very difficult task of teaching this subject, and who do not have any special fitness for teaching it. Some clear discernment, then, of possible ends to be attained will be of service here. Choice of a text and of a laboratory manual to be used, and all plans for shaping the routine of class management, should wait upon decisions concerning which of the aims set forth below shall control the instruction given. Changes in aim may be made at any time, of course, as suggested by results of teaching experiences provided these changes are consistent with intelligent efforts for attaining educational results of largest worth.

I. The General Science Course as an End in Itself

Whether general science be taught for one semester, one year, or be continued through the three years of Junior High School grades, its subject matter may be so chosen and unified that its teachings can be considered an end in and of themselves without reference to any later courses in science. In itself it may be considered as completing the science instruction of pupils whose schooling ends with the ninth grade.

A dominating motive in any such course will naturally be to provide discussions centering in the varied interests of home and community insofar as these relate to the teachings of science. These could very suitably be classed under the general heading "What Everyone Should Know." The applications of scientific achievement in social and industrial affairs generally will be stressed. Things of educational worth in science teaching, and which at the same time are "interesting" and "useful" though more or less unrelated as units of information, become of primary importance. Scientific conceptions set forth in the relationships of phenomena, and in the abstractions of scientific theories, are subordinated or completely eliminated. Experiments are introduced for illustrative purposes rather than to promote inquiry. Nor are these experiments chosen primarily to furnish training in thought processes which are based on observed facts, and which are incited by attempts to interpret

general truths through observations of typical phenomena. It is science teaching with the "science" left out. Nevertheless, its place in a curriculum is easily justified, and it is both an interesting and a profitable course of instruction.

In such a course the study of an automobile may be made, including along with instruction concerning names and adjustments of its parts and its various "controls" more or less discussion of the profound changes in social and economic affairs of men which have been brought to pass by its advent. Studies of radio, and of airplanes, and of a steam-threshing outfit on a western wheat farm, may be made highly profitable through employment of field trips and laboratory exercises in connection with information gained from instructors and use of books. There need be no teachings whatever in all this concerning the origin of soils, the physical conditions basic to an intelligent soil tillage, the chemical and botanical relationships involved in the growth of cereals, nor anything of the physics of soil and atmosphere affecting this growth. Nor is there need to mention the physics of internal combustion engines whether used in airplanes or in automobiles, nor any groupings of knowledge concerning electrical appliances in order to understand something of the generalizations of science in relation to electricity insofar as pupils in a class might be able to comprehend it.

For reference readings in these courses publishers'

lists furnish a bewildering choice of stories about the things of science, but not necessarily at all scientific in manner of treatment of the topics. Rich in valuable information, and highly interesting to pupils when presented by enthusiastic teachers, there is a natural tendency for these courses to become non-scientific, and "popular." Little is done in them, possibly, to establish mental attitudes and processes of acquiring and using information *in ways characteristically scientific.* A minimum of special preparation is required of a teacher for any such course, and no extended study of the different branches of science. Any of the texts on the market furnish content sufficient for a year's course, especially when reference readings are freely used.

II. General Science as a "Science" Course

Using the same topics as before, possibly the same texts, a course in general science may be made to center in certain selected sets of "laboratory exercises." These need not all be experimental in nature, but all require an interpretation of information a considerable portion of which has been gained first-hand. Of necessity such exercises must be simple in character, and should be chosen primarily for their teaching values in connection with science. Usually most of the experiments should be performed by the instructor. Accompanying the experimental work, and interwoven with it, should be as much instruction concerning related

worth while topics as the pupils can appropriate. The class period furnishes opportunity to carry out a "teacher's project" (p. 71). The pupils already have much information more or less vague, it may be, wherewith to interpret information now newly brought before them. Teaching efforts should be shaped chiefly towards a grouping of knowledge in accordance with scientific generalizations, while little if any scientific theory is mentioned. In other words, there would seem to be no good reason why general science may not be considered a "science course," sufficiently elementary in content and in difficulties to conform to the state of mind of those under instruction, but in spirit and procedure strictly in accord with the teaching of all secondary school sciences. The teaching stages in presentation of topics may very well be those which are summarized in the chapter on Teaching Cycle (p. 118). The amount of information to be gained experimentally, and considered fundamental to the scientific worth of the course, involves relatively few facts as compared with the knowledge already possessed by pupils. Life experiences are now supplemented by what becomes available through books, *but the content of these books is given significance by reason not only of these experiences but as well by the experiments witnessed.* These experimental exercises in certain cases may be performed by the pupil. They provide much if not all of the new "thought material" needed. The science

training lies in the manner of gathering and organizing the information possessed by pupils.

The written work required *like that in other science subjects on a laboratory basis* includes drawings, mathematical calculations, tabulations, summaries, etc., and these laboratory papers are to be handled as in any other laboratory course. Use of a textbook accords with discussions of preceding chapters. In short, *instructors in general science are expected to be science teachers.* They need to know in a rather general way much about secondary school science, especially the methods of teaching these science subjects. They need to be able successfully to select, adapt, and present topics from various sciences with a maximum of educational worth when measured as scientific information and training, *and suited always to the needs of the pupils under instruction.* The text in its vocabulary, its brevity of statements, and in its balanced choice and discussion of topics, is indispensable as an aid to the instructor's efforts, and to further initiative on the part of pupils. "Projects" as assignments for out-of-school efforts whether at home, in field, or factory are especially serviceable as teaching instrumentalities in connection with general science. Like projects in all other connections, the value of the results from them will depend in no small measure upon their being carefully planned in every detail, suitably supervised from beginning to completion, and particularly upon

whether or not pupils consider them as something worth doing well.

The literature of general science is embarrassing by reason of its abundance. Scarcely a publishing house which does not have one or more texts in general science together with laboratory manuals of varied form and content. Current issues and bound volumes of *General Science Quarterly* (Salem, Mass.), and of *School Science and Mathematics* (Chicago) furnish discussions of greatest helpfulness to teachers on various phases of this newly organized science subject. The apparatus and supplies needed depend, of course, upon choice of manual and text to be used.

Summary

1. Two distinctive aims in the teaching of general science.
   Factors which determine the one to be followed.
   Qualifications of teachers involved in choice of course to follow.
   Determination of choices of text and manual.
2. Dominant teaching motive where general science is taught as end in itself.
   Character of subject matter in such a course.
   Uses made of any experiments employed.
   Purpose of studies made of the applications of science in affairs of men.
   Extent of use of theories of science, and of training in scientific interpretations of phenomena.
   Teacher preparation involved.
3. Characterization of course when taught as a science.
   Purpose of experiments used.

Relative amount of subject matter employed. Chief end in its use.
Character of experiments, and by whom performed.
Written work required.
Teacher preparation involved.

4. Use of projects. Their kind, and limitations in use.
5. Literature available for teaching general science.

CHAPTER XX

BIOLOGY

Following the period of introduction of laboratory work into the high schools and academies such as then existed in the United States (1870-1890), there were exploited in the high schools various specialized phases of science one after another through many years. Very commonly these were college courses of a somewhat diluted form, and taught with laboratory requirements much the same as in college science. Many of these science subjects had but a brief career. This "fumbling around" with science courses in high schools brought with it a train of evils, not least among them being more or less loss in the relative importance of science in high school curricula.[1] In the judgment of educators very generally the teaching results of "science courses" were not at all satisfactory (pp. 191–193). Science in the public schools has lost ground in spite of an amazing world-progress in scientific achieve-

[1] Per cent of high school pupils in U. S. in who were taking:—

	1900	*1910*	*1922*
Botany	——	16.83	3.82
Zoology	——	8.02	1.53
Physiology	27.42	15.32	5.08
Biology	——	——	8.78

Bulletin No. 7 (1924), Bureau of Education, Washington, D. C.

ments, and a marvelous development of applied phases of science in the every day affairs of men. Bacteriology with its profound influence upon the health, happiness, and prosperity of mankind has had its marvelous development in less than two score years.

Despite the acknowledged importance of animal studies as part of an educational scheme, zoölogy as a high school science has never attained more than a precarious hold in the high schools of the country. In nature study there have ever been lessons upon various forms of animal life, including extended courses in bird study. General science coming into the schools provided further work upon animal life. But all too commonly these studies of animals have never been satisfactory in their continuity or their unity. Human physiology, apart from lessons in health and hygiene, at times was kept in the curriculum by legislative enactment. Here and there courses largely or wholly concerned with animal life were notably successful, especially in certain of the larger high schools as departmental work, and their success fully demonstrated the great educational value of these studies.

Courses in biology as more recently introduced into high schools mark a notable step forward in the crystallization and standardization of high school biological science. Years ago biology texts of great worth were available in high schools,[2] but these met no such

[2] Such as *Applied Biology:* Bigelow (1911). (The Macmillan Company.)

general favor as that which has prompted the publication of the numerous texts and laboratory manuals recently coming upon the market.

These older texts commonly had their content arranged to give a half year to botany, and a half year to zoölogy, including in the latter some more or less detailed discussion of the human body. Little or no attempt was made to point out the numerous similarities in life principles notably prominent in plants and animals. There was an encyclopedic array of facts, more or less isolated, set before pupils. Lacking desire to acquire this information whose purpose was not clear, botany and zoölogy retained places as science courses in high schools for what they might yield in educational values, possibly, rather than what was attained. The newer texts present biological principles, functions, and activities. They employ as illustrative material both plant and animal life. The emphasis is placed upon the similarity in living things—upon their life histories and habits rather than upon classifications and structural studies.

With the newly established one-year courses in biology there is projected further on into the high school curriculum the dominating idea of a more generalized (less specialized) science teaching, and a continuance upward through the tenth grade of the spirit and much of the method of nature study and of general science.

These later biological studies are supposedly unit

courses organized with reference to educational values rather than as fragments of courses in biological science. Mastery of botany, zoölogy, and physiology *as sciences* is left for college courses. Studies are made of plants and animals primarily to arouse, foster, and establish abiding interests in the living things found in the natural environment of those taught. A studied effort is made to provide as "thought material" suitable information concerning living forms, and to provoke and sustain thought effort wholly worth while in itself. Effort more particularly is directed towards the establishment of a mental attitude characteristic of nature-students and to train boys and girls in scientific ways of thought and investigation.

All this has its particular significance in the spirit and procedure of science teachers themselves. Any rearrangement and reorganization of subject matter, any modification in its manner of presentation from the kind of instruction heretofore given in the differentiated biological subjects, is supposedly dominated by a clearly defined purpose on the part of the instructor. This purpose is not to make the course necessarily in and of itself merely "interesting" to pupils, but instead that it constitute for them a means of educational development. With subject matter of a course suitably chosen, any methods employed in presenting this matter, and any devices used whether original to the instructor or otherwise, are but means only to a fundamental teaching end—the cultivation of keenness

of observation in pupils, and of intelligent interpretation of the vitally important facts of biological science.

Such is the spirit of generalized science teaching in contrast with highly specialized instruction in college courses. In no degree is there less need, however, on the part of instructors of a thoroughly unified as well as a general knowledge of biological science. For teaching uses, this knowledge must be definite though not technical, and so organized as to be available for concise and suitable modes of expression. Biology teachers must be grounded not only in the facts but as well in the theories concerning plant and animal life, including what has to do specifically with man himself. But in teaching high school pupils these biology courses are to be characterized by the endeavor in a larger measure than heretofore *to teach children in contrast with teaching science.* Neither confusion of meanings, nor conflicts in opinion, need arise here. The distinction suggested is one of aim on the part of an instructor, and of emphasis suitably placed. Changes in names of subjects in a curriculum, and any shuffling of topics as regards their order of presentation in any science, is far from attaining the educational progress sought.

This reorganization of knowledge concerning plants and animals, including human physiology, groups its subject matter with reference to the life interests natural to children. New sources of information concerning the natural world are opened to them, and as

well the great educational values inherent in the study of biological science. The admirable texts and laboratory manuals now available to teachers of biology often may vary widely in choices of subject matter, and in their order of topics. But this merely furnishes teachers of biology a larger range of teaching material suitable in itself, and adaptable to their particular preferences. There must be kept in mind at all times, however, *that responsibility rests upon an instructor to unify the topics chosen,* whether this be the order of the text used or otherwise. A course in biology is not a matter of so many weeks of time, but instead it should be a definitely planned period of closely related instruction and training. It must be a course adapted to the capabilities of the children, too, and productive of that somewhat ill-defined but very real educational end "a scientific mind."

So abundant and well-suited for courses in high school biology are the laboratory exercises to be found in the numerous "Manuals" in biology now on the market, it would be to little purpose to include here any type-lessons such as suggested for use in other connections (pp. 209, 300). Order Lists of laboratory apparatus and supplies will be governed by the experimental work determined upon, and must provide for experiments by pupils and for demonstration experiments by the instructor. It may often be possible to make arrangements for getting biological material direct from departments of botany and of zoöl-

ogy in some nearby college or university at moderate cost, and when needed for class uses.

Whether or not there be a fixed allotment of time, and certain days be specified for laboratory work to be carried on, the teaching of biology as of other high school sciences requires that there be enough laboratory exercises to provide all needed first-hand information upon any topic. These experimental results serve as centers around which in turn instruction upon any topic is organized. Every laboratory exercise, whether with plants or with animals, must in order to justify its use yield an abundance of "thought material" both in its results obtained and by reason of conditions involved. Likewise, it must incite to sustained thought effort by reason of the challenge it makes to an observer to comprehend what occurs.

Experiments are necessary in providing well-defined (not vague) ideas wherewith to understand both the teachings of the instructor and of the text. Too little of the possible teaching values in an experiment, in biological as in other high school sciences, is attained by any mere following of directions and the writing out of results gained. The maximum of instructional worth becomes possible when each exercise in turn has its educational possibilities exhausted by discussions of it while being carried out.

The unity of biology lies in its studies of living things, and the conditions under which life exists and is transmitted. It has to do with the nutrition, growth,

and structure of living things as well as the functions of their parts. All this is common to plants, animals, and the human body, but a wide range may exist in the different aspects of topics selected to form a unified course. Biology constitutes a science in and of itself rather than a composite merely of various sciences. Its unification through life processes and products is much like the unity of topics in physics as these center in and are related to discussions of matter and energy.

Biology, even as other high school sciences, can be so taught that its subject matter is a series of "problems" for pupils to solve, and in these solutions the various steps of reflective thinking may be compassed. Determination of just what this subject matter shall be constitutes a teacher's project (p. 71). In general, those biological principles which are of largest significance in life situations constitute the most suitable material to bring to the attention of pupils for thoughtful consideration and mastery. For determination of what such significant principles are the beginning teacher must needs rely largely upon selections made by textbook writers. Any modifications of the order of topics and content of a course to better fit local conditions, and the individual needs of pupils and of teachers, need to wait upon experience.

A common mistake in biology as in other science courses is an attempt on the part of a teacher to cover too many topics. The temptation is ever present, especially when following a syllabus, to give a sum-

marized logical presentation of the whole field without full realization till taught by sad experiences how little of the subject matter, and of inter-relationships of ideas gained from it, immature students assimilate.[3] It would seem wiser for best teaching results from high school courses to settle upon some few biological principles, those especially which are likely to be of large service during life in giving a better understanding of its biological aspects. These can be of a general rather than specialized nature, and their manner of presentation psychological as opposed to the systematic and logical. The need for reviews of what has been taught, and of renewed discussions of topics long since passed over in class, at no time should degenerate into saying over again statements of the same facts in the same language. Always there may be used a different "approach" to the same biological principle, and a new set of idea-relationships to the end that the knowledge gained is unforgettable.

The year's course in biology may be planned as a group of well-defined units, each centering in some feature of outstanding importance likely to make an appeal to high school pupils. These instruction "units" may include nutrition as a function both of plants and animals; respiration; reactions to stimuli, or nerve functioning; reproduction, and inheritance. Illustrations and discussions are to be from both plant

[3] Dr. Downing's range test on fundamental biological principles given to over one thousand students who had finished one year of biology was passed by 30 per cent of them only.

and animal kingdoms. Photosynthesis in plant growth can be related to teachings concerning energy in physics. Certain of these units lend themselves readily as projects in teaching, thus aiding pupils to make applications of their knowledge gained in schools to life situations. Knowledge of the life histories and habits of insects, including as it would studies of flies and of mosquitoes, readily finds application in a problem for ridding a community of these insect pests. One unit may well be historical, thus giving opportunity for students to come to an appreciation of contributions made to human welfare by such a man as Pasteur.

Methods and Equipment

It is highly desirable to have the laboratory and classroom one and the same room for smaller high schools especially. For instructional purposes only the same may be true for all schools though administrative needs in large high schools may dictate otherwise. Division of work in biology courses into lecture and laboratory periods is artificial and at its best wasteful of teaching possibilities. The subject matter under discussion should determine whether time be spent with a class in individual experimentation, in demonstration experiments, for study or for recitation. The advantage in use of the same room for all phases of science instruction lies in part in a possibility of change at any time from one of these aspects of instruction

to another as demanded by the progress of the studies. Where the biology room has laboratory tables and supplies as well as blackboards, lecture table, and classroom seating, conditions are most favorable for effective teaching.

For immature minds periods every day rather than double periods two or three times a week are desirable. A saving of teaching effort accompanies not having to spend the first part of every period in recalling the work of two days past, or more, and it alone makes the five-day-a-week plan worth while.

Equipment for biology teaching naturally is limited by funds available for the purpose. But generally speaking, and from an instructional as well as economic standpoint, the outlay is small compared with what is required for physics and for chemistry. The large outlay very commonly made for compound microscopes enough for individual work by laboratory sections in biology can, without serious limitations upon the worth of high school biology teaching, be largely dispensed with. There must be at least one good compound microscope for the instructor's use and for demonstration purposes, and several of them are highly desirable. Where funds available are ample, a projection microscope solves so many of the teaching difficulties of high school biology as to warrant the outlay involved in its installation. The instructor then is assured that all pupils have seen what is being dis-

cussed, and have all seen the same things pointed out to all of them simultaneously. Individual microscopic work then becomes of the nature of verification and extension of what has been learned by visual instruction, and from reference readings.

Elimination of any extended use of compound microscopes by pupils saves the time and energy used otherwise in cutting and mounting material for observation. It may be doubted whether high school pupils in general get large educational values from spending time, inexpert as these pupils necessarily are, in cutting sections which supposedly show what an instructor desires them to see. The conscientious high school pupil is likely to become nervously overwrought in getting what finally he may come to see; if not conscientious, he after a time learns to find in some textbook picture what he was supposed to see under the microscope. In both plant and animal dissections it is much the same. Time spent in amateurish butchery by high school pupils yields when carried through to its end specimens quite impossible of any satisfactory study. Discouragement, or dishonesty, is a likely outcome of these efforts. How much better is a demonstration by an instructor, perchance by using the projection microscope and prepared slides. Only when sufficiently expert to use profitably the time of a class for it, should an instructor make his dissections before the pupils. The full time and energy of pupils

is to be employed in getting an understanding of what is essential in these demonstrations, and through these an understanding of life principles.

Studies made of relative values of instructional processes in biology [4] show superiority for the lecture-demonstration method over individual laboratory work by pupils in teaching the principles of biology. Lecture demonstration work when well carried out establishes better idea-relationships, and what is learned is better remembered. This is true more especially because of the conditions of observation, and the "setting" given the particular facts sought through observation. It is true here as in other high school science teaching that experimental work may be carried through by pupils who at the same time fail to grasp the significance of what was attained by it, and who fail to be stirred to thought effort by it. The goal in teaching is, of course, getting the maximum of instructional value from the experimental work undertaken, and this is not necessarily proportional to the number of experiments worked. The same investigations showed, too, that pupils prepared by a semester of lecture-demonstration method when put to individual laboratory work were more successful in manipulation and in interpretation than were they who had been trained in individual laboratory work from the first.

Much of the material used in biology teaching must be living specimens. That it be at hand when needed

[4] By Dr. E. R. Downing: University of Chicago.

for use requires no small amount of judgment and use of foresight on the part of an instructor. The biology departments of large city schools may have material from the school greenhouse as needed, but teachers very generally must depend upon gleanings from fields and gardens, from homes and meat shops. Window boxes for plant growths and germination testings may be made in the manual training department. All glassware, including (it may be) an aquarium, together with the apparatus found listed in catalogues of biological supplies and needed for laboratory exercises whether by pupils or instructor, involves no appalling expenditure. It may be desirable, and often will be necessary, to scatter these purchases over several years and buy in accordance with a definite plan for a final complete equipment. Supplies and apparatus if needed only occasionally may often be had from the physics and chemistry laboratories.

In high school biology the value of a notebook depends largely upon the purposes and the persistency of an instructor A concise record kept by pupils of experimental work observed, whether performed by the pupil himself or by the teacher, combined with statements concerning its purposes and the significance of the results obtained, is valuable even as in other science studies. It makes opportunities for scientific ways of thinking and for an expression in writing of the results of laboratory exercises. It is especially conducive to reflective thinking when the written work

follows a completed series of experiments. The orderly manner of making records of the conditions observed in experimental work, of the results obtained, and of the conclusions reached supposedly based upon facts known, tends towards the establishment of a scientific approach when solving problems other than in biology. Where the nature of exercises requires that drawings be made in order to make manifest whether or not pupils have gained the concepts desired, carefully labelled diagrams serve this purpose well. These do not take the time that artistic drawings require. The educational worth of such drawings from pupils in general scarcely warrants any insistence upon more than diagrams. Encouragement is at times to be given, of course, to pupils who manifestly possess talent for drawing. Such pupils should be content only with the best that they are able to do. These diagrams and drawings at all times are but means to an end rather than ends in themselves. In all thought expression thus graphically set forth, there should be the least outlay of time possible that is consistent with clearness of expression in the relationships of ideas gained in and by reason of the experimental work.

Summary

1. Relative importance of science in high schools now and formerly.
   Nature of earlier science courses.
   Importance of science in the affairs of men.

Zoology in high schools. Other studies made of animal life.

2. Contrast in high school courses in biology now and at earlier periods.
   Dominant purpose of the later biology courses.
   Central theme of these one-year courses.
   Modifications in teaching procedure which are involved in them.
   Teacher-preparation required. "Spirit" of these biology courses.
3. Texts and manuals now available for use in high school courses.
4. Equipment required.
   Compound microscopes, and their usefulness.
   Conservation of teaching energy, and of pupil effort.
5. Biology as a series of teaching units. Its unity.
   Purpose of experimental work.
   Number of topics covered.
   Some major divisions ("units") of a course.
   Projects in the biology course.
6. Instructional processes in high school biology.
   Method in general to be followed consistently.
   Relative values of lecture-demonstration, and of individual-laboratory work, with classes of beginners. Instructor's part in each.
   Notebooks. Drawings.

CHAPTER XXI

PHYSICS

No question arises in the teaching of high school physics, as in the case of general science, whether or not it shall be taught as a science. It is taken for granted that its subject matter as selected for high school pupils should be organized and presented with reference to theories which account for, or explain, physical phenomena. It is taken for granted, too, that there shall be experimental work as part of a high school physics course. But, there exists in the teaching of physics in general even as in the teaching of general science a distinct line of cleavage in the manner of its teaching, the importance of which is measured by the grief it has occasioned pupils and teachers of physics alike. That this difference in teaching procedure arises from a purpose on the part of a teacher, which in itself may be more or less vague and ill-defined, makes its existence none the less real. *It is largely a question of fitting the subject to the comprehension of pupils as opposed to an effort to make the pupils fit into a concise and therefore difficult presentation of the theoretical and mathematical aspects of physics.* In the one case the applications of physics

II

Tables for Physics, and Use Generally in Science Teaching.—Width 34″; length 15′4″; thickness 1½″. Table tops are 31½″ above floor. The hollow iron pedestals have flange at floor 10″ in diameter, and at top 8″ in diameter. Their diameter midway up is 4″. Shallow drawers for each pupil may be provided, but add to the cost to little purpose. Gas and electricity are readily provided at these tables. There is great economy in floor space, and ample room for instructor to pass behind pupils for inspection of their work. At all times they face the instructor's desk, and at a moment's notice change may be made from experimental work and writing to class instruction.

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in the affairs of men are made matters of major interest along with interpretations of phenomena, both natural and experimental, introductory to generalizations in terms of laws and theories. On the other hand, theory dominates the teachings, with sufficient applications of a mathematical and practical nature needed to convey the meaning of what is authoritatively taught as the summation of man's present knowledge of physics. The two methods of approach are suggested but not sufficiently described by reference to them as inductive and deductive, the two merging in due time into a single teaching "cycle" as pupils progress.

All shades of opinion on the part of teachers of physics, and all degrees of adherence to either viewpoint, are to be found. Such extreme views find expression at times as set forth in statements that from twenty to thirty per cent of high school pupils registered in physics should not be expected to "pass," and that these same pupils are of course likely to "hate" the subject of physics. In college physics instructors have been known to state an intention of "failing" a third of a class, thus making it apparent that the physics taken under them as instructors was no "snap course," and making sure that high standards of teaching were maintained in their work at least.

One method of presentation to beginners in physics is to take an attitude somewhat the same as in the teaching of general science when taught on a labora-

tory basis. This is the making of such choices and adaptations of subject matter, and especially to have such manner of presentation of it, that every pupil in a class who puts forth a reasonable amount of effort shall be profited greatly, boys and girls alike, by a year's study of high school physics. Physics can be regarded as a foundation for other science studies not only in the sense that its phenomena as studied in relation to matter and energy are preliminary to and find their applications in other sciences, but because of its large possible training values in the establishment of scientific attitudes of mind, and a scientific manner of thinking.

Differences of opinion exist, wholly honest and sometimes very earnest, whether the teaching of high school physics shall be strictly scientific in its manner of presentation, or whether primarily the intellectual advancement of pupils shall be sought even at the sacrifice of more or less of its theoretical and mathematical aspects. This involves decisions on the part of teachers whether or not it is desirable to make sustained efforts for developing and directing a "desire" (a) to know more both of the teachings of physics, and of science in general; (b) to learn as distinguished from a need to get "credits"; (c) to seek that knowledge which is valuable in life situations rather than mere information soon forgotten. As viewed by pupils there are involved two considerations: (1) whether or not that which is taught has real worth to them; (2)

whether or not it is a means for attaining ends other than school grades, powerful as the immediate appeal of these may be. It involves, too, the question of shaping the physics teaching for the sake of educational values to all pupils who take the subject in contrast to efforts to maintain certain "standards" of what high school pupils should be expected to learn in a physics course.

No divergencies of opinion held by teachers of physics in these matters need be occasion for heated arguments and antagonisms. The one time dominant place of physics among high school sciences to some extent has been sacrificed through lack of adjustment of conflicting opinions held by teachers of physics. During changes incident to the notable expansion of secondary school instruction taking place in the generation now past, readjustments have occurred in the nature and relationships of high school subjects materially affecting physics as one of these subjects. Especially has this been true concerning subjects included in high school curricula serving different groups of pupils, and various specific teaching ends. In these changes the relative importance of physics in high school courses has lessened. Courses in household physics even as in chemistry of the household have been organized. In and of themselves as high school sciences they are but makeshifts at best, however justifiable such courses may be under certain conditions of school instruction. The real issue is one of

teaching worth in general for a beginning course in high school physics leaving applications of it in engineering, home economics, agriculture, and other fields for later and perhaps for college courses. In nowise, however, does this preclude the largest possible use of whatever information of home and vocational nature pupils may have, nor of making applications of the teachings of a general course in physics in any field wherein it finds immediate and suitable application. This is but sound teaching procedure in general. So far as an elementary or beginning course in any high school science is concerned, no differentiation is required for various groups of high school pupils.

Where teachers as beginners have not become fixed in their views and ways of teaching secondary school physics, it would seem there should be special emphasis and insistent demand that physics like all other science subjects be taught for its educational worth. Especially should this be the case in all teacher-training institutions where physics teachers for the smaller high schools are likely to get whatever of special preparation they may have for science teaching. As a science required of all high school pupils, any commanding place of physics among science subjects must depend upon indisputable evidence of its instructional worth. The organization of a physics course must not be such that its presentation as "science" is at the expense of good pedagogy, and in disregard of educational principles founded upon accepted teachings in educational

psychology. Choices of texts, of manuals, of laboratory experiment lists, and of the manner of use of experiments in connection with instruction given topic by topic, all wait upon determination of what dominates in any teaching procedure consistently followed. Much if not all of what has been said is equally applicable to large and small high schools alike. While many teachers of physics have taken no courses in education as such, and others may have specialized in physics preparatory to teaching it, without exception the single controlling aim for all teachers of physics whatever their preparation for teaching service should be the educational interests and welfare of their pupils. The situation is one in which the instructional efforts must not be diverted from the general good of all pupils to that of the few who later perchance may become masters in scientific achievement. Such is the genesis of public schools. Physics in secondary schools is for general educational ends rather than for making physicists.

Much which has been said elsewhere of a general nature (See *Laboratory Equipment, Place of Laboratory Work, etc.*), is as applicable to the teaching of physics as to other high school sciences. Mention has previously been made that teachers of experience do not need to be told their needs, and how these are best met. However, the teaching of physics is undertaken every year by those who are not only inexperienced but who at the same time are not especially well fitted

for the attainment of desired teaching results. The suggestions which follow should be taken in connection with discussions previously given. Until by reason of successful teaching efforts a teacher has developed wholly satisfactory ways of his own, it is the part of wisdom to follow courses suggested by the experience of others.

In a general way the time of a one year's course in high school physics should be divided about equally between laboratory and classroom work. Three periods of class discussions and instruction, with two double periods given over to exercises of experimental nature, should suffice. Where a smaller amount of time is available for the subject, certain selected parts only should be studied rather than any necessarily superficial treatment of the whole subject.

It is to be borne in mind that the expenditure of time and effort by a physics teacher in preparing for experimental demonstrations, and in conducting class exercises with laboratory work, is necessarily greater than that required for a recitation or lecture of the ordinary teaching type. In school programs a differentiation should be made between a teacher with demonstrations and laboratory equipment to prepare, and one who simply has subject matter to master. Especially is this true in schools where inadequate or defective equipment results in a heavy demand upon the time of a teacher in providing apparatus. One way of meeting these conditions is to assign fewer class

periods to a science teacher. In many schools, and in part because of these conditions, the sciences have been parcelled out among different members of the teaching force according to an ever shifting personnel, and as personal preferences may dictate. Distribution of the teaching load is thus accomplished at the cost (theoretically at least) of a conservation of teaching effort possible when the "science" of a small high school is centered as a unit in one instructor, or in one department. Physics in particular has suffered in this way.

The laboratory part of a course in physics should include experiments of a quantitative nature. The best sources for these without doubt are the many excellent laboratory manuals in high school physics. So far as possible every pupil should be thrown wholly upon his own individual efforts in working any quantitative experiment, and forced to rely upon his own judgment in the evaluation of results obtained. A certain few experiments may require group effort in securing desired data.

Aside from qualitative experiments performed by the teacher, illustrating and enforcing the teachings of a class period, many simple experiments of a qualitative character should be performed by pupils themselves preparatory to discussions of these topics in a next succeeding class period. In this way there is secured a very definite understanding of the meanings of terms employed by teacher and textbook, a first-hand knowledge of phenomena to be brought under

discussion in class, and an appreciative attitude toward whatever instruction is then given. Quantitative experiments may very properly follow class discussions as applications in general of instruction given. In making selections of these experiments such as are of "practical value" are preferable. Quantitative experiments lacking elements of precision in manipulations required, such as inclined plane, siphon, etc., should not be allowed to displace experiments of greater value as laboratory work. The metric system commonly should be used in all measurements, and decimal fractions in all calculations. Pupils should learn to think in and to make estimates of quantities in metric units and tenths of units.

The classroom should be especially well lighted, and so seated that clear unobstructed views of what is being done at the lecture table may easily be had by every pupil. The lecture table should contain many drawers and compartments for supplies, and for storage of those smaller accessories so necessary to have at hand when giving demonstrations. The table should be provided, too, with water and a sink, and with gas and electric connections where these may be had. There should be curtains for darkening the room, and some device for reflecting sunlight from a south window across the lecture table. The top of the lecture table preferably should be somewhat lower than the level of the eyes of the pupils when seated in classroom. Rather large portraits of some few noted physicists on the walls of

the room are both instructive and inspiring. Abundance of the best of blackboards must be provided.

The laboratory when a separate room should be large and well-ventilated. One and the same room can be used to excellent advantage for both class and laboratory uses when provided with long narrow table tops of substantial construction. These are supported preferably on iron pedestals with flaring bases fastened solidly to the floor. Light, strongly-built chairs may then be used for seats on the one side of the table only, the pupils all facing the instructor's table. (See Appendix B.)

Free wall space is desirable for suspension of apparatus to which pupils in turn may be sent. Bracket shelves on the walls are useful in many experiments when the building is free from serious jars. A water supply and sinks are essential in a physics laboratory, but not so many are needed as for chemistry. In modern school buildings these needs are carefully provided for in the school architect's plans. There should be cases for supplies and apparatus in the room when possible, otherwise in an adjoining storeroom. A small workbench and some few tools likely to be needed in construction and repairs may very profitably be provided. A manual training department with its motor-driven lathe, drill-press, etc., serves many a need of the science teacher.

Where classes are not large, and other conditions permit, a double period every day gives time for lesson

preparation under supervision as well as for laboratory and class work. A physics teacher then has a large degree of freedom in use of this time for experiments or other laboratory exercises, for class work, or for lesson preparation as may seem best with the work in hand. The same room may thus be used very satisfactorily for all phases of physics instruction, a case with reference books to be consulted at will by pupils becoming an essential part of the furnishings.

For many of the experiments of a year's course in high school physics simple apparatus for the instructor is quite as indispensable as the more elaborate and expensive instruments. Where funds are not ample, apparatus of the simplest kind should be secured rather than some few costly pieces; but at no time should its effectiveness be sacrificed for cheapness. All apparatus purchased should give reasonably reliable quantitative results. There should be no lack of glass tubing, rubber tubing, rubber stoppers, files, clamps, ringstands, test tubes, flasks, metric rules, wire, thermometers, etc. In general, the equipment required is of two sorts: (1) apparatus for classroom demonstrations using experiments of qualitative character in connection with class instruction; (2) apparatus for individual laboratory practice by pupils in order to provide them training in manipulation, to develop habits of precision and accuracy, and to secure an intelligent observation of phenomena presented before them. A wise expenditure of one or two hundred

dollars for use in the physics teaching of smaller high schools goes far towards providing a satisfactory working outfit to begin with. A small annual outlay should then be made for permanent equipment. In placing orders for supplies and apparatus a catalogue of some reputable supply house is indispensable. Its cuts, descriptions of articles, and range of choices as indicated in part by prices listed, secures a better assortment of what is needed for any course settled upon, and lessens likelihood of mistakes and disappointments from orders filled. In general it marks the difference between a judicious expenditure of funds, and a haphazard frittering away of opportunities to get the most for any outlays made. It might be added, too, that when in doubt concerning items to be ordered the advice of teachers of experience in ordering might profitably be sought and heeded. Much apparatus suited for laboratory uses, especially electrical supplies, is oftentimes most satisfactorily purchased through the regular "trade," thus getting commercial instruments built for industrial uses. Appearance at times may well be sacrificed for utility. If, for example, a "blow-torch" be needed in laboratory uses it may be well to order it through a hardware house handling plumber's supplies. The necessity amounting to an imperative need that suitable cases for storage of apparatus be provided has been mentioned elsewhere (p. 40). These cases must be kept locked when apparatus is in place. The wastage of moneys invested in laboratory

supplies and apparatus permitted by some teachers is occasion for much of the limitations in these respects experienced by their successors.

Summary

1. High school physics as a science.
2. Choices of teaching aims characterized.
   Extreme views of relationships of subject to pupils taught.
   "General science approach" in physics teaching.
3. Changed standing of physics as a high school subject.
   Occasion for loss of standing among high school science subjects.
   High school physics a unit course. Later differentiated phases.
4. Teacher-training for high school physics teachers.
   Purpose of physics teaching in high schools.
   Wise course for the inexperienced teacher of physics.
5. Suggestions as to:
   (a) Division of time between class and laboratory work. Total of hours per week.
   (b) Instructor's "load" as a physics teacher.
   (c) Experiments—qualitative and quantitative. Their special purposes each as a class.
   (d) Use of metric system of measurements.
   (e) Seating and lighting of classroom. Wall cases and shelves, window shades, blackboards, wall decorations.
   (f) Furnishings of lecture table and of room.
   (g) The laboratory and its furnishings. Water, gas, sewage, and electrical connections.
   Work bench and tools.
   Service from manual training department.

(h) Use of same room for class, laboratory, and study purposes.

6. Apparatus and supplies for use of teacher, and of pupils. Order lists. Commercial instruments.
Storage of apparatus. Responsibilities of teachers in care of apparatus.

CHAPTER XXII

CHEMISTRY

I. Its Teaching in General

So striking and even fascinating are many chemical phenomena suited to studies in elementary science, and so numerous and important are the chemical changes of all sorts in everyday experiences of life, that at first thought it would seem that chemistry should be found in all high school curricula. Attempts to maintain such courses are, however, not always so successful as might be desired. Where these failures have been chiefly or wholly due to employment of teachers unfitted for what they undertook, the remedy is obvious. Nowhere sooner than in high school chemistry does teaching incapacity become more quickly and strikingly apparent whether due to lack of mastery of the subject matter, inability to adapt what is known to the needs of pupils taking the course, or incapacity for laboratory administration. Then, too, the best of teachers in high school chemistry must not be expected to accomplish the results desired with inadequate equipment, impossible room conditions and lack of maintenance.

III

Locker Case for Chemistry Laboratory.—Made of oak. Non-corrodible drawer pulls. Key to single lock kept by instructor (or assistant). Drawers 10″x14″x5½″ inside. Posted list of apparatus, with prices for each item as charged to pupils, at M.

The prominence of chemistry in connection with the Great War attracted the attention of the public. There has been increase in the number of students taking chemistry, notably so in college courses. The demand is insistent that instruction given in high school chemistry be of a manifestly high order. While very few of those beginning the study of chemistry will follow it vocationally, its educational values are so great for high school pupils as to warrant extended consideration of the difficulties attendant upon teaching it, and more especially so where in high schools the teaching conditions are more or less unfavorable.

Among pupils entering upon the study of chemistry there is in evidence at times a desire to "fool around" with chemicals and laboratory apparatus "just to see what happens." Perchance one may stumble upon a great discovery! Discernment of the purposes of a high school course in chemistry is lacking. It is not clearly understood that the wonderful achievements in chemistry, together with what is being done and what is hoped for in promoting the welfare of man, comes only at the conclusion and not at the beginning of courses in chemistry. Vague and extravagant notions on the part of pupils of the entertainment and freedom to be enjoyed in a course in chemistry later prove stumbling blocks in the instructional processes. Waning interest and cessation of efforts follow inevitably when the fallacy of these notions becomes apparent.

Procedure with regard to choices and uses of labora-

tory manuals and texts, conduct of laboratory work, and teachings of theory from facts gained by observation, are discussed elsewhere, and generally in ways especially applicable to chemistry. The transition in science teaching from laboratory exercises in the hands of the teacher only, to laboratory work carried on by pupils individually, becomes complete in high school chemistry by reason of the ages of pupils as well as the nature of the experimental exercises. In making choices of experiments primary consideration of necessity is given phenomena which furnish the teaching situations needed. Otherwise, choices should have local and industrial relationships since these furnish subject matter of interest to pupils. More particularly, the facts under discussion should be such as lend themselves later to organization through use of the theories of chemistry. In all the earlier stages of a beginner's course, and through the first semester at least, it must not be forgotten that the terms employed make chemistry a study of a new language.

When facts enough have been accumulated to justify it, then and not till then is it best to enter upon discussions of any chemical theory by use of which to group, or "explain," the facts at hand and all other facts of like nature subsequently acquired. As in the study of other high school sciences, the value of chemistry is to be judged by its worth educationally, not by the amount of subject matter mastered. It offers unexcelled values in the training of pupils in scientific

methods. The best of these values for chemistry centers in that habitual reaction of mind which demands that all needed knowledge available be summoned and judiciously applied to the solution of the innumerable "problems" arising in connection with the routine of instruction in the subject.

To secure the best teaching results with a beginning class, it is advisable to avoid attempts to cover an undue amount of the vast fund of information available even when suited to an elementary course in chemistry. This is applicable especially to the descriptive portions of the various topics included in a course. Texts and manuals commonly furnish more material than can be covered adequately in a year's time by beginners. Selections of material to use, and the amount of time for class and laboratory work, must take into account primarily the abilities of the pupils in the class, together with the conditions under which instruction must be given. No large measure of judgment is required, especially when based upon some teaching experience, to adapt a chemistry course to teaching situations. It is necessary, of course, to maintain the natural relationships of topics to one another, and to the interests of those being taught, and none of the fundamentals of a beginning course should be omitted.

Five double periods per week are highly desirable for high school chemistry whenever this is possible. Practically no home work then is made necessary. All

laboratory work carried on by pupils should always be in double periods. Strict adherence to alternation of class and laboratory work is unnecessary. The best of teaching results may oftentimes be had by continuing for a week at a time, it may be, either laboratory or class work. Classroom conditions should be such that demonstration experiments are possible at any time.

The manner of instruction for the first weeks of the course is vital to success. The inferences which constitute so large a part of the teachings based on laboratory exercises are difficult for high school pupils. Especially is this the case when they have not had an excellent preliminary training in arriving inductively at judgments of their own *based on observations made by themselves.* The language of chemistry, its formulæ and its equations, easily bewilder pupils when working at their best. Textbooks in high school chemistry in their first chapters commonly fail to furnish pupils the assistance so greatly needed by beginners. In many cases these books are good illustrations of how not to start a course. A systematic presentation of topics suitable for college students seems to presuppose on the part of beginners in high school chemistry ability they do not have for the comprehension of chemical changes, and a clear discernment of the controlling conditions in these changes. Even instruction given by teachers of superior ability in nowise makes

the textbook in and of itself any less indispensable at this most critical period of the course.

The text is for the pupils. It is to be referred to over and over again ("studied") by them when in need of detailed information concerning what is but slowly comprehended. It supplements and clarifies what the instructor can do for them, and furnishes background and purpose for the laboratory requirements. The inclusion in modern texts in high school chemistry of the many things "new in chemistry" has resulted at times in an omission of those beginning discussions of processes and studies of chemical phenomena simple of interpretation and fruitful of instructional opportunities. Authors of chemistry texts seem of one accord in considering these as having no place in the study of chemistry, not permissible even in a "first course" in chemistry.

The lesson on Combustion (p. 220) may belong in general science, but it is suggestive of one manner of approach to a study of oxygen, beginning in the realm of the "known." In it there is a presentation to pupils of one difficulty at a time. Where pupils are capable of going more rapidly to more difficult and involved studies, it could of course go unused. It employs as material for thought a fund of knowledge which the pupils may be presumed to possess by reason of their experiences in life. In a study of the oxidation of iron, or other metal, the pupil under guidance may learn

for himself that a gain in weight results; that air surrounding the metal loses in volume, not all the air participating in the change; that the active part of air constitutes about one-fifth of the whole volume; and that this part long ago received the name oxygen. In some such natural way let the beginner in chemistry be given opportunity to develop a spirit of inquiry, and a desire to learn the ways of acquiring knowledge in this hitherto unknown field. Sustained effort to master the difficulties of the first stages in the study of chemistry needs at all times the assurances of achievement, of something accomplished day by day that is intelligible.

When enough examples of combining proportions have been commented upon in class, and when cases of multiple proportion have repeatedly been noted, the atomic theory may then be presented as adequate explanation of the general weight relationships summed up as "laws" of definite and multiple proportions. When in addition to studies of solubility, the diffusion of gases, and discussions of the molecular hypothesis as accounting for these facts of solution and diffusion; when the "laws" of combining volumes of gases have been shown experimentally, it is time to advance Avogadro's hypothesis just as he himself advanced it [1]

[1] *Molecules, Atoms, et Notations Chimiques:* Libraire Armand Colin, Paris. (Les Classiques de la Science). Or, see a translation from the original essays of Gay-Lussac and Avogadro in *A Teacher's Handbook* to accompany *Foundations of Chemistry:* Blanchard and Wade. (American Book Company.)

to account for these findings of Gay-Lussac. The facts of electrolysis should precede the theory of Arrhenius, and the facts of radio activity should lead up to the modern views of the complexity of the atom. Much time must elapse in getting these groups of facts before a class in proper relations to experimental work done by teacher and by pupils. Any extended teaching of theory necessarily comes late in the course, and only after pupils have attained some considerable degree of laboratory skill, some familiarity with chemical symbolization, together with an ability to interpret both experimental phenomena and the generalizations of the text. Premature discussions of theory bring disaster to a course. Any considerable use of equations, too, should wait upon the accumulation of sufficient experience so that very largely they set forth *what is known as facts,* rather than what is surmised to be true. Pupils may manipulate a prodigious number of these equations as matters of memory, and at the same time comprehend but little of their significance.

It not infrequently occurs in the latter part of a second semester that there is a notable falling off in interest on the part of pupils. In taking up studies of the metals there not uncommonly is a marked change in methods of instruction. The texts furnish a mass of data upon the carbonates, chlorides, sulphates, etc., of the metals about as stimulative of thought as any other tabulation of data. These groupings of facts furnish excellent material for memory "quizzes," but

lacking suitable and simple preliminary laboratory exercises may be as barren of interest and of significance as are chronological tables of historical events. It is at this stage of the work that projects (p. 68) will at times be found exceedingly helpful.

The content of a year's course is well set forth in a report [2] by a Committee On Chemical Education of the American Chemical Society on "A Standard Minimum Outline" for high school chemistry.

II. Laboratory Discipline

Certain problems of laboratory discipline are more or less peculiar to the teaching of chemistry. One difficulty which many young teachers encounter in laboratory management arises from the comparative freedom in moving about and in communicating with one another which pupils in a chemistry laboratory enjoy in contrast with the enforced quiet and order of classrooms. This difficulty really brings with it its own remedy if rightly met. The very freedom of the place acts as a safety valve for any exuberance of spirit. A teacher may call the attention of a class at the outset of a laboratory course to the fact that more liberty of action should obtain than in the classroom, but that this liberty is not to be taken as license for disorder. The first law of the laboratory is attention to business. Pupils as a rule respond to such a fair appeal tactfully

[2] *School Science and Mathematics* (XXIII: 777).

made. Should any one fail in this respect, prompt and firm action on the part of the teacher is imperative. No issue or controversy is necessary. Loss of laboratory privileges should follow abuse of this freedom.

It is essential that training in laboratory habits start at the first of the term. Otherwise a noisy and disorderly group is almost certain, and a condition may result difficult to control. It is sufficient usually that a disorderly pupil be sent from the laboratory, either to the Principal's Office or to a study room, and that he be required later to make up the lost time in the laboratory. A talk at that time with the pupil about the necessity for a decent degree of order in the laboratory, and some reasonable pledge for his co-operation in the future, usually is all that is required.

The chief requirement for a wholesome laboratory atmosphere is a business-like attitude towards all its administrative and instructional features on the part of the teacher. That sort of spirit is contagious and the membership of a class as a rule will go about its work with a similar attitude. Many things may be tolerated at times by some teachers which would be deemed out of order by other teachers. As an example, animated discussions among members of a group of students at times can safely be permitted to go on by some teachers even when marked differences of opinion over the facts of any experiment, and over the significance of such facts, may be rather loudly proclaimed. Such outbursts are to be endured only so long as the

pupils engaged are really thinking. Whatever fails in any such discussions to lead to something definite and worth while is disorder, and must be checked by any teacher when unlikely to subside of itself. The weaker the personality of a teacher the less of such risk should be taken. Meddling with apparatus not called for by the directions should not be tolerated.

In addition to this attitude of teacher and pupils from the outset towards the laboratory work, a certain amount of planning must be done, with resort made at various times to devices which have been found helpful by teachers of experience. One ever-important matter is to provide sufficient room for each pupil in laboratory work. Crowding invariably leads to disorder. Another item is to give such seating arrangements that when pupils are required to work in pairs as they may be at times, there shall be from the first a wise selection of teams. Usually it is better to pair boys with boys, and girls with girls, for obvious reasons. In all other respects it is wisest generally to allow pupils to select their own companions. By so doing, and without need of giving any directions concerning it, differences of social rank which might be violated by the teacher are likely to be avoided. One source of friction in laboratory administration is thus removed. Colored pupils should in general work together, but always in a part of the laboratory with no marked disadvantages over the other parts. It is sometimes well, when the relative capabilities of pupils

have become known, say at the beginning of a second semester, to arrange pupils in pairs of approximately equal ability, rather than permit the brilliant and the dull to be unequally yoked together.

As boys are by their very nature likely to be more noisy and boisterous than girls, it may at times be wise to arrange seatings so that pairs of boys are "well insulated" from other pairs by pairs of girls. Pupils known as likely to overstep the bounds of orderliness may be given places where at all times they are under the teacher's eye.

Seemingly small matters such as these, when planned wisely and tactfully carried out, avoid much trouble. The best laboratory discipline, indeed, is that condition where no disciplinary measures are in evidence. The attitude, then, of teacher and class toward the work in hand becomes a concerted effort "to make the most" of the time and opportunities of the laboratory for instructional ends. One help to good order in the laboratory is a suitable placement of any supplementary apparatus so that pupils may get it, and replace it, with the least possible travel. Pieces of apparatus most frequently needed should be available in larger quantities, and so placed as to be closer to the pupils than supplies less often used. Cases conveniently placed in the laboratory should have shelves and drawers reserved for pieces of apparatus to be used in common by pupils as needed at the tables. If a little time be taken at the outset of each course to train

pupils to replace all such apparatus when used, much subsequent bad housekeeping will be avoided.

Where all pupils in a section are likely to need pieces of apparatus and material not set out where pupils may serve themselves, it saves time and confusion to have one or two pupils distribute the requisite supplies to the others. This should not be allowed to replace self-service where there is any educational merit in the act as, for example, when an experiment directs the pupils to "weigh out accurately one gram" of a substance.

III. Laboratory Equipment

The need to dilute acids before allowing them to enter the waste pipes, and the necessity of preventing stoppage of waste pipes by solids, calls for a greatly increased size in waste pipes over what is ordinarily provided for sinks. The materials used in plumbing sometimes must be of special type to prevent rapid corrosion. Probably pure lead makes the best material for the pipes. In a chemistry laboratory the lead pipes when used should be brought up into the sink itself, and not soldered to the usual brass connections since the latter last but a short time because of acids in the waste. Where stone sinks are used, the lead waste pipe should be about two inches in diameter. It may be flared at its inlet and sealed into the hole in the sink by means of a paste of red lead and linseed oil, or some similar material.

IV

Chemistry Tables.—From the locker L each pupil gets and brings to his place at the laboratory table at the beginning of a period the drawer of apparatus issued to him. The broad shelf below the table top furnishes a place to set aside these drawers after taking from them such articles as may be needed, whether at first or later. The pupil, at the end of a period, returns his own supplies in the drawer to its place in the locker. The table tops are 10'x4'x1½", and three feet up from floor. The shelf below is 33" wide, and 16" from floor. The reagent shelf is 19" above the table top and may, when desired, be omitted from the construction, thus lessening cost without any great loss in serviceableness of the table.

From wall racks such as R reagents likely to be needed during a period may be transferred to the tables in advance of laboratory work, and afterward replaced by student assistants, thus leaving the tables cleared for janitor service. A posted list C of reagent solutions suitably numbered facilitates these replacements. The wall sink S has drainboards where washed apparatus may be left to dry, but all other apparatus should always be returned to their place. These wall racks are 52½" long with five shelves 9" apart, and 5½" wide.

Small jars for table waste (not here shown) may be drained into the alberene sinks, and their solid contents dumped into large stoneware jars for the janitor. Stools in sufficient numbers are to be had as needed from places at one side.

Pure lead "thimbles" one-fourth-inch thick, shaped like a low stovepipe hat, and drilled with numerous one-fourth-inch holes in the top and around the upper sides, when sealed over the end of the sink waste pipe serve to strain out the solids and to keep water standing an inch deep in the sinks for dilutions of acids. These thimbles can be made and placed by the teacher, a brass mould first being made at a machine shop into which to run molten lead. Openings in the thimbles should be numerous enough to accommodate the flow of more water than both faucets can deliver when wide open. Such an arrangement of lead thimble and lead waste pipe will last for years. It is extremely desirable that pipes for water, gas, and waste be laid above the floor level in order to be accessible for repairs without tearing up the floors. Individual cut-offs should be supplied for each desk. The larger waste pipes that drain several desks or laboratories are best made of seamless lead-lined wrought iron or duriron pipes [3] leading into tile sewer pipes in the basement. All fixtures in the chemical laboratory such as draw pulls, hinges, latches, etc., should be of *solid brass,* and not brass-plated iron, that they may resist the corrosive effects of the acid gases of the laboratory.

Where notebook cases are kept conveniently near the door so that pupils can quickly get their notebooks on entering the room, and then leave them on going out, a marked gain in promptness of starting

[3] Duriron, a silicon-iron, is excellent material for waste pipes.

work will take place. Notebooks then are always at hand when needed by the pupil or by the teacher. Portable cases, home-made if necessary, permit carrying these notebooks back and forth between laboratory and classroom. In small schools such provisions as these are unnecessary. But where hundreds of pupils visit one department daily great gain results, and efficiency in laboratory service is promoted, by following these or some similar administrative means for securing a minimum of waste and a maximum of work in the laboratory.

Reference books should always be available in the laboratory. There should be a convenient and suitable place to keep them on some wall shelf, or in a sectional book case. Pupils should be able to get these reference books without disturbing or distracting the attention of other pupils and always without leaving the room. This disposition of reference books is even better than the use of a separate departmental library room, involving as it does less travel back and forth, and fewer supervisory responsibilities on the part of an instructor. As with apparatus and materials, so pupil helpers at all times when desired can pass out and later replace all duplicate copies of reference textbooks in use. Some one of these pupils may serve as laboratory librarian whose special duty it is to note at the close of every laboratory period whether or not all books are back in place.

By observing the spirit and some of the method of

these suggestions, a teacher will find his laboratory discipline consumes much less of his energy, leaving him free for the all-important individual instruction which is so valuable a feature of laboratory work.

Summary

1. Chemistry in high school curricula.
   Character of instruction demanded.
   Misapprehension of pupils registering for chemistry.
2. Relationship of chemistry teaching to that of other science subjects.
3. Introduction and usefulness of theory in chemistry.
4. Amount of subject matter to be covered.
   Rate of progress for classwork.
   Double periods for chemistry.
   Alternation of class and laboratory work.
5. Special difficulties of the first weeks in chemistry.
   Notable deficiencies of texts.
   Introductory lessons. Inductive teachings.
6. Theories of combining weights. Avogadro's hypothesis.
   Time for discussions of theory.
7. Equation-writing.
8. Lack of interest in studies of metals. Lack of relationships of facts.
   Use of projects.
9. Plumbing for chemistry laboratory.
   Dilution of acids before draining into pipes.
10. Metal fixtures of the laboratory.
11. Laboratory discipline as a problem for beginning teachers.
    (a) Freedom of the laboratory for pupils.
    Advantages taken of this by pupils.

Remedy for laboratory disorder and confusion. Relation to this of prompt correction of first cases.

(b) Correct habits of the laboratory.

12. Aids to orderliness of laboratory from suitable working space, and wise seating assignments.
    (a) Arrangement of apparatus for least moving about.
    (b) Student assistants.
    (c) Notebook shelves.
    (d) Library in laboratory.

APPENDIX

APPENDIX A

LESSONS IN MORAL TRAINING

In all discussions of science teaching much emphasis is laid upon the need to keep always in consciousness the facts of any situation under consideration. These facts as "thought material" (a) must be assured truths and not mere surmises of unverified statements concerning facts; (b) they must be evaluated with reference to relative importance while being acquired, and their mutual relationship established as matters of inference. As the result of more or less complex thought processes conclusions are reached *based upon known facts.* These conclusions in themselves serving as working hypotheses have their valuations attested in applications to life situations. Confidence in the worth of all conclusions reached is based upon the degree to which they accord with the life experiences of individuals and of the race. Likewise, in the problems of professional life and of the business world, a ready mastery of the facts as to conditions which are ever changing, and a promptness in deciding upon working hypotheses as conclusions based upon facts, *underlie all successes attained.*

Need exists for a like attitude and procedure in moral education. The experiences of public schools, however, are too often summed up in a declaration that science teachings and training do not "carry over" into the realms of moral education. Vital as education in morals is claimed to be to life's largest possibilities, both personal and social, its applied aspects as part of training processes in public schools may be characterized at the best as hap-hazard. Little can reasonably be expected from such efforts. There are many difficulties which chill the ardor and baffle the purposes of teachers, conscious of their responsibilities as positive and constructive forces in the moral life of their pupils. There is a lack of clear discernment of the series of steps to be taken, and the significance of these steps in a truly scientific procedure, and inability to handle the "human element" in the reaction of pupils to moral teachings and practices when authority as personified in the instructor ceases to exist. Teaching experience warrants the assumption of intuitive responses by pupils to all moral influences whose uplifting effects are clearly discerned by them. Were such not the case, ethical and spiritual advances of the race must necessarily be fitful and evanescent. Natural perversity of human nature may or may not be a wholly satisfactory explanation to offer for the inability often apparent among men and women as well as children to discern and keep in mind the facts upon which right conduct as an exposition of character

is based. Both in science teaching and in moral education an ability to use terms fluently is uncertain evidence of any appreciation of the meanings back of those terms.

All attempts to secure the formation of habits of right response in morals necessitates recalling certain ideas which taken together serve as standards, and which at the same time furnish motives for right conduct. The number of such facts constituting the subject matter in moral instruction is relatively small, but they offer much the same difficulty of comprehension as those involved in undertaking to specify just what constitutes the "personality" of an individual. In the lessons which follow there is a studied effort to have the instruction cluster about certain significant phrases the very suggestion of which later, whether given formal utterance or not, *is a call to face the facts* of situations involving the moral element in conduct. This feature in a training process is and of necessity must be individualistic in the extreme. It is a matter private rather than public, and preferably incidental as to time and associations. While the emotional life in order to maintain a healthy state must find full and free expression for people generally, the springs of emotional life are hidden. Bared to the public, and subjected to the pitiless criticism and unrefined cruelty of classmates, they dry up and disappear from view, and the best intentioned efforts of faithful teachers are unlikely again to gain access to them.

Some Type Lessons

The lessons which follow suggest a teaching procedure in a course of moral instruction immediately applicable in school life as well as elsewhere. The complementary course in moral training is intended to develop keenness in perception of moral values, and positiveness in right moral reactions to life situations. Any such lessons can suggest only what the earnest painstaking teacher must himself develop in order to exert lifelong uplifting influences in the lives of successive generations of pupils. In the lessons which follow there has been an endeavor to preserve with a minimum of adaptation some of the content but more particularly the spirit of certain lessons whose use by another [1] in a masterful way has been witnessed by one of the authors, exerting an influence upon his own teaching through many years.

(1) WHICH CLASS ARE YOU IN?

A. Introductory discussion:

1. To what class (or grade) in school do you belong? Why are you in this class rather than some other? Who put you into this class? As a result of what tests were you assigned to this class? How long did

[1] Dr. A. W. Norton, one time of the Elmira (N. Y.) public schools, Oswego (N. Y.) State Normal School, Peru (Nebr.) State Normal School, Sioux Falls (So. Dakota) Baptist College.

it take for the assignment to be made when once these results were known? What should be the effect on one's desire for promotion of any failure to get into a higher class? What effect has a long continued stay in any class in school upon personal appearance in later life? How is change to a higher class secured? Under what one heading might all these items determining your classification be placed?

(Then follows a tabulation [2] at the board by the teacher of the matter in columns (a) and (b) shown below, the teacher writing line by line as needed what is given in column (a), and then filling in under (b)

[2] The answers gained from the pupils in the preceding discussion, or their equivalents, will when tabulated present some such forms as the following:

(a) *Classifications*	(b) *By knowledge*	(c) *By character*
1. Name of class one is in at school.	Senior, Junior, etc.	Good, or bad.
2. Why this class rather than another.	Age; scholarship.	Earnestness in right doing; or, carelessness, laziness, viciousness.
3. Classifications made by whom.	Teacher.	Self.
4. Basis for classification.	Examinations.	Conduct.
5. Time required for assignment to any class.	At once.	Gradually from many acts.
6. Effect of failure to be promoted upon desire to get out of a class.	Stronger desire.	Indifferent to it.
7. Effect on appearance in later life of any long stay in a class.	None.	Very great.
8. How changes in classification are brought about.	Sustained right efforts.	Repeated right (or wrong) acts.

what has been agreed upon by pupils as above. In substance this is not likely to vary greatly from what is given in the tabulation.)

2. Into what two classes may all people conveniently be grouped with reference to conduct? Name some things which characterize the people of each class—what they are, and what they do. Who is responsible for the behavior of an individual, and for the class in which he is? Who, then, puts him into that class? According to what is the class to which he belongs determined? How long a time is required to determine this classification, *i. e.*, how rapidly is it brought about? What effect has a long continuance in one of these classes (a) upon one's desire to get out of it; (b) upon personal appearance in later life? How alone is changing from one to the other of these classes to be accomplished?

(Column (c) of the tabulation is now to be filled in at the board as pupils agree upon what shall be written. This is likely to be much the same as what appears in the tabulation.)

B. Write-up period:

(Pupils are to copy from the board the tabulation worked out by teacher and pupils and written there by the teacher in the preceding stages of the lesson. The papers handed in are not to be returned for obvious reasons in view of later use of the same lesson with other pupils.)

C. Applications as pertinent queries used at opportune times later:

In which class are you today? How long are you going to stay in it? Who put you into it? How will you get out of it? When will you begin making effort to get out? How did you get into the bad class? Why be in such a class? How many years does it take for anyone to become hopelessly bad? Name some one whose bad conduct you desire to imitate. Why not?

"Don't be in a hurry with little Jim.
God knew 'twould take years for a man to grow,
He knew the job would be very slow,
So don't you be in a hurry with Jim.
Perhaps Jim is wasteful, perhaps he is slow,
Perhaps doesn't think that his elders know.
Well! That is the way God grows a man.
God might have done better, but we doubt if He can.

"Jim stumbles today, but he'll come right yet,
God knew 'twould take years to grow a man,
He knew the job would be slow and long,
To grow a man with a will that is strong;
A will which breaks every stone in its way,
A will which brings a glorious day;
A will which climbs to God's mountain height,
A will which bends every force to the right.
If God can wait for little Jim,
Don't you be in a hurry with him."

Eleanor Scott Sharpless.

(II) TELL YOURSELF

A. Introductory discussion:

1. Who in a family is likely to tell the children to get up in the morning? Who tells the father (or mother) to get up? Why is this?

Why not expect a little girl always to tell herself what to do? What is a difference in this respect, too, between a boy and a man? How, then, is a boy to become more and more like a man? What change day by day is true of a boy as to age? What should be true of his size and strength? What after all at any time is a still more satisfactory test of whether a boy really is becoming a man of worth and power in the world? How after all is it really established that one whose age is twenty years or more, whose weight is one hundred twenty pounds or more, and whose height is six feet more or less, really is a "grown-up" and not a child? Give a brief definition each for man and boy making it especially clear wherein lies this change from childlikeness to manliness. (A man "tells himself" what to do, and what not to do. A child *has to be told what to do;* and, if necessary, made to do it.)

2. Give some illustrations of what it is to be denied. What is meant by self-denial? How many people experience denial of their wishes? Give an illustration of denials which society imposes (a) upon travelers on highways; (b) upon those who have contagious diseases; (c) upon those who do not respect the property and rights of other people.

In telling one's self, who decides what is the right thing to do? Why may parents not always allow children to decide what to do? In dealing with "grown-ups," why the need of police, constables, and sheriffs? What generally is the occasion for courts, judges, and juries? What is society compelled to do with those who will not "deny themselves," and who refuse to "do right"? When only is society justified in setting these individuals free from confinement, and allowing them to go their ways at will in the world? Only upon what basis should the decision to free them be made?

B. Write-up period:

1. Give illustrations of the denials which society imposes upon those (a) who would practise medicine, or dispense drugs; (b) who prepare and sell foodstuffs in regard to weights, names, and purity; (c) who appropriate to their own use what belongs to another?

2. What denial does nature impose upon those who (a) for many years make a practice of overeating; (b) continue to use stimulants and narcotics?

3. What in a general way determines whether or not it is right to do any particular act (a) insofar as it affects one's self; (b) as it affects others?

4. Distinguish between doing right and doing wrong. Give illustrations.

5. How long a time is required to get ready to do right? What are advantages in doing right as a mat-

ter of habit? Who really are the strong men and women of a community, and in the nation?

6. What significance as to being "grown-up" has any manifestation of a mean spirit in dealings with others? Where one is physically well, what does shiftlessness and laziness signify?

7. Why so generally does a horse in harness start or stop just as desired of him, or turn when travelling to the right hand or the left? What uses have the reins and bits of a harness? What is it to be a well-behaved horse? [3]

C. Pertinent queries for use at opportune times:

Are you ever going to be a man? When? How am I to know it?

In those many cases of school discipline where the "gang" is involved, and the plea is "He led me into it": Are you planning always to be a horse led (or driven) about? Who to-day has the reins? When are the bits to come out of your mouth? Who is to take them out? Why not be driver and "tell yourself" what to do?

(III) THE MASTER WORKMAN

A. Introductory discussion:

What was it formerly in the trades and industries to be an apprentice? Names of any noted men of science as Benj. Franklin, or Michael Faraday, who

[3] Brownell: *Text in General Science* (Blakiston's Son & Co.), pp. 25-30; 64-84; 209-213; 293-296.

served as apprentices in youth. What were the purposes of an apprenticeship system as regards (a) the individuals themselves; (b) industrial conditions?

What substitute is there today for apprenticeship in industrial life? Relative advantages and disadvantages of apprenticeship, and of lack of it? What part are American schools coming to play in this condition?

B. Write-up period:

Copy of tabulation below after it has been developed under direction of the teacher as in lessons before. *Papers handed in are not to be returned.*

Making a Success of an Apprenticeship, And of a Life.	*In Apprenticeship*	*In Life*
1. When each starts.	At 12 years of age, possibly.	At birth.
2. What is necessary to insure success.	Early choice of trade.	Devotion to life work chosen.
3. What should lapse of time bring.	Increase in pay, and promotion.	Increase in ability to do, and of enjoyment in doing.
4. Results of long service.	Skill.	Character.
5. Results of careless service.	Discharge, discredit.	Bad character, a ruined life.
6. Result of increase in skill.	Lighter work.	Tasks made easier and more enjoyable.
7. How ability to do is to be gained.	Long service, attention to business.	Right use of opportunities.
8. Ideals cherished.	A better workman than the boss.	To be Godlike in attributes.
9. When a master workman.	In the course of many years of skilled service.	Through perfection in service.

C. Pertinent queries:

Who is your "boss" in this? (Any matter of conduct.) How long an apprenticeship are you serving? What is to be your reward? When do you expect to become a master workman, and fit to "tell yourself"? How? When your present opportunity for service has been lost, what are you going to have to show for it? What rewards are you looking for? (In cases of questionable practices.)

(IV) BE A MAN

(The introductory discussion and the write-up following are here omitted. These may be supplied readily enough from the tabulation which appears below. The plan is that of the lesson on "Which Class Are You In.")

Comparison	*Horse*	*Man*
1. Character.	Good (or bad).	Good (or bad).
How judged.	By acts.	By acts.
2. Control of actions.	By owner (as master).	Self-controlled (or should be).
3. Responsibility for acts.	The master's.	Personal—one's self.
4. Rule of life.	None.	Do what is right.
5. Motive for acts.	Impulse (emotion).	Principle (some rule).
6. Aim in life.	Physical welfare—have food, drink, ease.	Right living physically, mentally, morally.
7. Attainments.	Just a horse—no more.	Nobility in character. An enduring personality.

Queries: Who (among associates) is driver today, telling you what to do and how to behave? Whose

bits are you wearing today? Why be a horse led about (directed) by others? (By their sneers, or threats, or example.)

Why not be in control of yourself rather than mastered by impulses (or passion)? To what impulse will you yield next—ungoverned rage, a fighting mood—what? Are you a creature of impulse today, or a man of character governed by principle? How do you expect to retain control over your emotions (yourself) *i. e.*, by what rule will you be guided?

Why not always go ahead and do just as you feel like doing? Convince me now that what you did (any act) was not done just because you "felt like it." When are you to begin doing as you ought rather than as you feel? Why doesn't a horse even do always just as it pleases? Why not be a horse? By whom should a man be made to do what he ought to do?

APPENDIX B

BLACK FINISH FOR TOPS OF LABORATORY TABLES

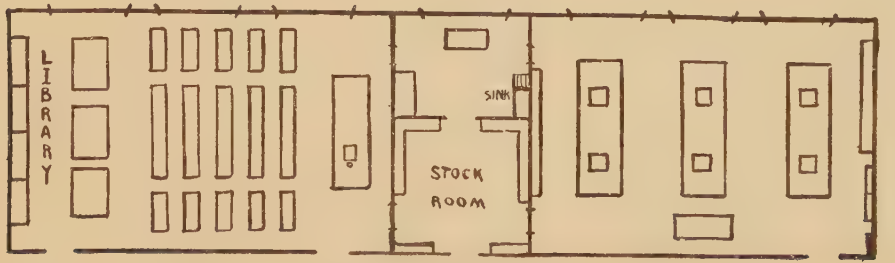
I. Solution "A":

625 grams copper sulphate
625 grams potassium chlorate
5000 cc. water
(Apply two coats hot.)

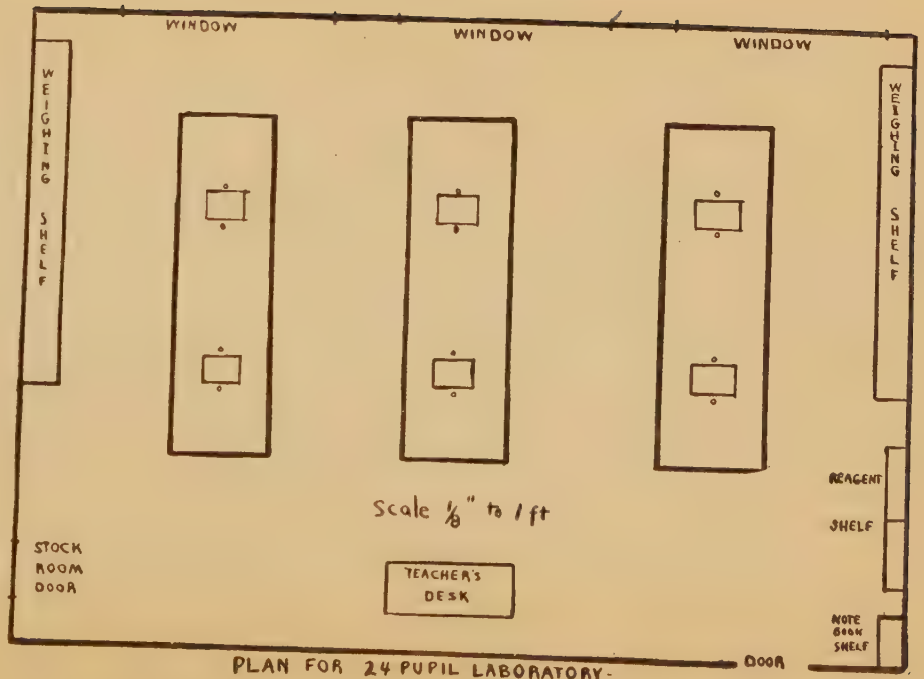
II. Solution "B":

150 grams aniline hydrochloride
1000 cc. water
(Apply two coats hot.)

III. Finish with raw oil, using turpentine to thin oil, and put on hot. Then wash with hot soap suds.



PLAN FOR LECTURE ROOM, STOCK ROOM AND
LABORATORY
SCALE 20' to 1 inch



PLAN FOR 24 PUPIL LABORATORY-

APPENDIX C

RANGE OF INFORMATION TEST

FOR SCIENCE TEACHERS

Date ..... Name .....

University of Nebraska
Teachers College

Science subjects you studied in High School .....
.....
Hours credit you have in college sciences .....
.....

Directions

By word, phrase, or concisely worded sentence explain as many as you can of the following fifty scientific terms. Write as quickly as you can, and do not abbreviate too much. WRITE LEGIBLY, and in fine (not coarse) script. Try to give real meanings, and always the scientific rather than any common non-scientific meaning. Where a word has several scientific usages give the one you can define best.

Now in the left margin, and just before each numbered term, put an X before every term of which you feel that you know little or nothing. Then, before every term which you think you have defined or explained put an O. Those

left unmarked will then be terms of which you have knowledge which is so vague and indefinite as to be of little immediate use to you.

List of Words

1. Acceleration (in motion) .....
2. Antiseptics .....
3. Candle power .....
4. Cellulose .....
5. Center of gravity .....
6. Chlorophyll .....
7. Comet .....
8. Cyclone .....
9. Density .....
10. Dew point .....
11. Disease organism .....
12. Electrolysis .....
13. Environment .....
14. Emulsion .....
15. Equilibrium .....
16. Evolution .....
17. Family tree .....
18. Fertility of soil .....
19. Diffusion .....
20. Gluten .....
21. Horizon .....
22. Humidity .....
23. Hygiene .....
24. Image .....
25. Immunity .....
26. Incandescence .....
27. Insulated .....
28. Ions .....

29. Law of pulleys .....
30. Molecule .....
31. Momentum .....
32. Natural selection .....
33. Osmosis .....
34. Pasteur .....
35. Phases of moon .....
36. Plant (or animal) cell .....
37. Protein .....
38. Radiation .....
39. Sanitation .....
40. Satellite .....
41. Sedimentary rocks .....
42. Saturation .....
43. Specific heat .....
44. Spectrum .....
45. Sprain .....
46. Sterilization .....
47. Tendons .....
48. Vacuum .....
49. Voltaic cell .....
50. Water "hardness" .....

Number left unmarked of which knowledge is indefinite ....
Number marked X .... Number marked O ....

On the back of these sheets write at length, and in concisely worded paragraphs, what you know of the theories associated *with any one* of the following terms: (a) heredity; (b) electronic theory; (c) Avogadro's theory; (d) conservation of energy.

Turn in your paper at the end of.....minutes.

APPENDIX D

SOME NATURE STUDY LESSONS

The Mouth

1. In what part of the head is the mouth cavity? Name the walls by which it is surrounded. To what else besides the cavity is the term mouth applied?

2. Describe the structure of the lips. What is the form of opening between the lips when wide apart? How much freedom of motion have the lips, and how is this secured? Name the several uses of the lips.

What can be told of a person's feelings by noting the lips? How may lip expression be affected by an oft-repeated emotion? Explain the natural redness of the inner surfaces of the lips and of their edges.

3. Of what use are the cheeks? What is their structure?

4. Observe the rear wall of your mouth as seen in a small mirror, and describe what you see. Name its various parts. What is the name of the cavity farther back?

5. What is the character of the roof of the mouth? Which wall of the nasal cavity is it? If all the walls of the mouth were of bone, in what respects would its usefulness be affected?

6. After studying it closely with the aid of a mirror, describe the structure, lining, and general appearance of the floor of the mouth. Note the movements and the structure of the tongue, and explain its mobility.

With the finger-tips pressed against the outside of the throat about where the tongue seems to be rooted, ascertain if possible to what it is attached. Of what advantage is an attachment of this kind?

7. Describe the form, size, color, and coverings of the tongue. Note how it may be rubbed against the roof of the mouth, and state what is accomplished by this action in eating. Mention other uses of the tongue in eating.

8. For a person who is in good health, what is the appearance of the tongue as to (a) moist look; (b) coatings? What information is really sought by the physician when he "looks at the tongue"? What is tonsillitis?

9. State the location of the teeth in the mouth cavity, and their general arrangement. Why would it not be as well to have muscle in place of bone for the jaws?

10. State the number, general characteristics, and duration (a) of the first set of teeth; (b) of the permanent set. Classify the permanent teeth according to form. State the number, form and special use of each of these groups.

11. Name the parts of a tooth. Which part is exposed in the mouth? What are the gums?

Why should we take good care of the teeth? How

often should attention be given them? What should be done, and what avoided, in order to preserve the teeth?

Make a study of a tooth obtained from a dentist, or elsewhere, and tell the place and nature of (a) dentine; (b) enamel; (c) pulp.

12. Where are the voice sounds produced? What is the function of the mouth in speech? What are the bad results of breathing through the mouth? What are adenoids, and when may their removal become necessary?

13. Aside from its use in speech, what is the chief use of the mouth? What uses has the saliva? By what is its flow affected? Where is it secreted?

The Eyes [1]

1. Describe the location of your eyes with regard (a) to the body as a whole; (b) to the face as a whole; (c) to the nose.

2. Of the eyeball tell (a) its estimated diameter; (b) the general form of it as seen with the eyes widely opened; (c) the names of the several visible parts; (d) the form, color and relative position of each part. In which part of the eyeball can changes in size be noted?

3. Watch closely the movements of the eyeball, and tell in what directions it can be made to move.

4. Make observations of the eyes of several people

[1] Use a small mirror for the study of your own eye.

and state what differences you observe (a) in the depth to which the eyes are set in the head; (b) in the amount of ball exposed; (c) in the general appearance, luster, expression, movement and other characteristics.

5. Mention any important purpose apparently served by having the eyes placed (a) so high up in the body; (b) at the surface rather than deeply set.

6. What protection has the eyeball (a) at the sides; (b) in front?

7. Of the eyelids state (a) the significance of the name; (b) their structure; (c) the form of each when the eye is closed and when open; (d) their relative size; (e) the amount of motion for each; (f) the place of the eyelashes.

8. Describe the nature, form and length of the eyelashes. What is their apparent purpose?

9. State (a) what would result if all secretion of the tears were to cease; (b) how the tear-water is spread over the eyeball; (c) how much of the time the eyeball is kept moist; (d) from what point under the lids the tears flow; (e) the significance of water running from the nose when one cries; (f) why the tears do not overflow the cheeks all the time; (g) the course of the tears across the ball.

10. When a bit of dirt or any solid particle gets under the eyelid, what may be done to remove it?

11. What uses have the eyebrows? In what respects are they unlike in different people?

12. What defects of the eye are common?

13. What care should be taken of the eyes as to (a) direction whence light comes; (b) amount of light; (c) continuous use of the eyes; (d) general health?

14. Discuss briefly the importance of sight.

Some Wonderful Stories About Limestone

1. Shell Animals

Material: Various shells as snail, oyster, or clam; coral; lump chalk; blackboard crayon.

1. Personal experiences of teacher and children in the collection and study of shells as an "Introductory Discussion."

2. Story of oysters, and the oyster industry. (Bigelow [2], pp. 405-416.)

3. Test of a shell with HCl or other strong acid. Conclusions as to its nature. Manner of growth of shells contrasted with the growth of plants, and of animal tissues such as bone.

Uses of its shell to an animal. Values of an internal rather than external skeleton to animals generally. Locomotion of shell animals. Source of the material for shell building.

4. Nature of a solution. Solubility of any shell when left in water.

5. Story of coral. Tests with HCl. (Bigelow: pp. 336-339.)

6. Test of school crayon with HCl. Account for the residue in tube after action of acid ceases.

[2] *Applied Biology:* Bigelow. (The Macmillan Company.)

Story of chalk. Nature and uses of (a) whiting; (b) putty.

7. Story of pearls, and of the pearl fisheries. (See some encyclopedia.)

2. Origin of Limestone, and Its Uses

Material: Limestone; marble; lime; cement; pictures.

8. Tests with HCl of limestone, and of marble. Earthy deposit in tube.

9. Story of limestone formation. Extent of limestone as one of the rocks in the earth's crust.

Its present location in elevated inland districts accounted for.

10. Marble quarries, and uses of marble.

11. Quick lime, and slaked lime. The chemical changes involved in making them. Lime-water. Mortar for builder's use. Whitewash.

12. Nature and making of cement. Concrete.

3. Solutions Containing Calcium Compounds

Material: Pictures; calcite crystals; fossils; lime-water.

13. Test of one's breath by lime-water. Effect of excess of CO_2, and the chemical change involved.

14. Cavern formation in limestone strata.

Descriptions of such a cave with its chambers, passages, stalactites and calcite crystals.

15. Crystal formation from solutions.

16. Fossils of limestone, and their history. Geyser basins.

17. Explanation of the "lime" found on the inside of tea-kettles.

One way of "softening" laundry water.

Use of washing powder to "break" hard water for laundry uses, and something of the chemical changes involved.

18. The "lime" in bones of the human body. Whence derived, and how built around the living cells of bone tissue.

19. Values of limestone in soils with reference to plant growth.

The Weather [3]

1. Some Properties and Uses of Air

1. Empty a filled bottle of water. What goes into the bottle as the water flows out?

2. Press a bottle mouth down into a jar of water, and over a floating bit of cork. Explain why water fails to enter and fill the bottle.

Repeat having an outlet through a rubber tube for the air that is in the bottle.

3. Through a pipette, whose large end reaches down into water in a tightly stoppered bottle, force as much air as possible from the mouth into the bottle. Withdraw the mouth quickly to one side. Explain the fountain effect.

[3] By permission from *Laboratory Lessons in General Science:* Brownell. (The Macmillan Company.)

4. Where about us is air to be found? Attempt to grasp a handful of it. Account for the inability to do this. Point to any air that you see.

5. Look at a pencil through window glass. What property of the glass is manifest? Remove the glass, and look at the pencil through air. What property of air is manifest?

6. What odor has pure air? What taste?

7. Name several uses served by air (a) when still; (b) when in motion as a wind.

8. Write in a column a list of a dozen things you have known the wind to do. Then in a column, and opposite every such act, write adjectives characterizing it, using such words as saucy, tireless, gentle, angry, etc.

Mention the various names given to winds by reason of variation in their force (intensity).

9. What are the names given to winds according to the directions whence they blow? Name several ways in which wind directions may be somewhat accurately noted.

10. Tell of the importance of winds to mankind in commerce. In what ways do winds minister to man's comfort and to his discomfort? In what ways do winds affect man's health?

2. Weather in the Affairs of Men

1. When we indulge in talks upon the weather what commonly is the nature of our comments in connection with (a) temperature; (b) atmospheric moisture, and

precipitation; (c) winds; (d) state of the sky; (e) relation of weather to crops, and trade; (f) effect on our health and the well-being of people by reason of weather conditions?

2. What in a general way is the relation of temperature (a) to latitude; (b) to altitude; (c) to locations far inland as contrasted with nearness to oceans?

3. In a general way compare conditions in the very cold regions, the torrid, and the temperate as regards (a) the productiveness of the soil; (b) the working efficiency and productiveness of both man and his domestic animals.

4. State any relations apparent between changeable weather conditions and (a) the prosperity of people; (b) variety in their occupations, skill, and productiveness; (c) their advancement in learning.

5. In what two chief ways has the human race sought to protect itself against weather changes aside from the matter of food supply? In modern civilization by what added and modified ways do we protect ourselves from (a) extremes in temperature; (b) exposure incident to travel and out-of-door occupations?

6. What effect upon people (a) of the excessive year-around heat of the torrid regions of earth; (b) of the continuous cold of the polar regions; (c) of sudden and extreme weather changes; (d) of long continued wet periods or dry spells?

7. Of what advantages to people may weather forecasts be when reasonably accurate? Upon what must

such predictions be based to have any special worth? For about how long in advance can forecasts be made that are reliable?

8. About what is known of the causes of deficient rainfall in any region some years, and excess in other years? What control over these conditions has man? Explain what the mountain ranges of western United States have to do with any semi-arid sections to the eastward of these mountains.

9. What conditions of surface make irrigation possible for large areas of land which are well suited for agriculture when an ample water supply is provided? What industries are made possible in irrigated districts? What advantages and what disadvantages of living on irrigated lands? Describe any extensive irrigating system of which you have personal knowledge, or of which you have acquired definite knowledge by reading.

APPENDIX E

A PROJECT IN CHEMISTRY

In the second semester of a high school course in chemistry the teaching conditions are highly favorable for getting excellent results with projects. A wide range of industrial aspects of the science, and the intimate relationships of chemistry to nutrition and growth in plants and animals including as this does the human body in states of health, makes the subject matter of chemistry well suited to a relatively large use of projects. The divisions and sub-divisions of topics in chemistry are clear-cut, representing distinct fields of study. The maturity of the pupils in a 12th grade, and their extended training in laboratory procedure, warrants expectations of highly valuable educational results from the more capable pupils. There is a wealth of literature in chemistry, too, admirably suited to such uses, and it at once becomes a storehouse of material adaptable to the needs of high school pupils throughout a wide range of projects.

In place of furnishing here a "List of Projects," it has seemed likely to be of greater helpfulness to follow out the details of one such project as typical of others naturally suggesting themselves to an instructor. In

the course of a teacher's work many others more or less adaptable will be found noted in text and reference books. The prime requisite for success in the use of projects applies here as elsewhere, viz., a hearty cooperation on the part of pupils, and that degree of initiative and resourcefulness which shall make the project one for the pupil rather than the teacher. The guidance of many of these projects simultaneously carried on by pupils as individuals, or at times working in groups, and the verification or disapproval of some of their claims, will provide for the busy chemistry teacher one of the many ways in which to employ his "spare time."

Let it be supposed that the instructor for any one of various reasons desires to depart from the formal teaching procedure, and at the same time make a study of Sodium, And Its Important Compounds. For a "survey of the field," a series of "problems" may suitably be set forth as topics in the form of questions, such as the following:

How is baking soda made from common salt?

What is the nature of baking powder? What purpose is served by it in cooking?

What is "soda ash"? What its use in glass making?

How is dry, free-running table salt made from crude rock salt?

What are (a) washing soda crystals; (b) washing powders? What is the use of either in laundry work? What is (a) "climaline"; (b) "sapolio"?

What is Chili saltpeter, and its relations to (a) fertilizers; (b) high explosives? What is Glauber's salt, and its preparation, and use?
What is the "oxone" employed in making oxygen? What is the action by which oxygen is liberated?
What is caustic soda? What use has sodium hydroxide in the soap-making process?

It will be noted at once that the foregoing list of inquiries covers as compounds of sodium the oxide, hydroxide, chloride, nitrate, sulphate, carbonate and its hydrated crystal forms, bicarbonate, and phosphate. In the course of the project pupils will need to prepare all these substances, preferably from the same materials used in commerce, and possibly by use of the same methods. They will require assistance in the way of suggestions as to manner of approach in different operations, and considerable guidance that time-waste and discouragement be minimized. Less and less help should be necessary as the work goes on.

In general a class of pupils working upon a project of such scope as this may subdivide it along lines suited to the topic, and may work in groups whose combined report shall complete the project as a whole. To the largest degree possible any student should have choice of his part. After class projects in chemistry have been completed, especially if pupils have had projects in other science subjects, a much freer choice can be permitted even to work carried on independently. These choices must at all times be consistent

with laboratory facilities, the capabilities of the pupil, and avoidance of any risk of accidents. At the outset of the work pupils should find out as much as they can about the nature of the material with which they as individuals or as a group are to work,—its history, its laboratory preparation, its manufacture. A committee in charge may assign parts of these efforts to certain pupils, and include in these assignments the theoretical aspects of problems covered by the project, and the actual steps in laboratory preparation of any substances studied. Through this committee various aspects of the project are kept abreast, and the project more promptly completed as a result of "group activities."

Notes should be kept by individual pupils, and from these notes written accounts of each phase of the project should be prepared for a report to the class as a whole under direction, it may be, of a "committee." These reports should be made at some set date, and made much of even to an abandonment of laboratory work for the time needed to give and discuss the report. The class should take notes of items reported, and every pupil should be given a chance to ask questions for his own enlightenment, or for clarification of what has been poorly set forth. The committee reporting should likewise prepare a suitable set of questions for dictation to the class as basis later for an examination covering the subject matter of the reports. This gives the committee a splendid opportunity to practice the

selection of the essentials of a project. A more searching examination should be given any group upon its own part of a project than the class as a whole. These "major" and "minor" examinations furnish excellent opportunities to estimate relative abilities of pupils, and they afford desirable variety in work for the pupils.

When project work is first started all needed reference books should be made accessible, and pupils taught how these books are used to best advantage. They soon will learn which books are rich in historical matter, and which are best for theoretical or industrial aspects of their problems. In these ways pupils may be expected to gain the "reference habit" in use of books. Some prodding of individual pupils may at times be necessary so that they do their parts of the work, and close oversight is necessary that everyone be kept busy. This is incidental to and not in conflict with the idea of initiative and persistency of effort on the part of pupils when at work on a project. These pupils have not yet attained the age of independent effort as workers, *but as yet are pupils in training.* The project type of work so appeals to pupils, however, that it may be counted upon in time a majority of them will go ahead with their particular projects with the greatest of profit to themselves. The spirit of mastery engendered reacts most favorably upon the regulation types of teaching as carried on along with *teachings by use of projects.*

By frequent consultations with his pupils the teacher

can see to it that every point he himself would bring out if teaching the subject is brought out by one or another of the pupils during the presentation of reports. In the case of the sodium compounds as above, should the teacher desire to have hydrolysis taught, the pupil whose study was washing soda having noted the reaction of litmus to a water solution of the normal salt should have studied the accepted explanation of this apparently anomalous effect, and should report these findings to the class. Again, the "baking-powder pupil" finding aluminum sulphate in some baking powders will need to make report on hydrolysis in connection with the acid reactions occurring in his problem. The class thus gets several different approaches to important teachings concerning such items as these, especially where the work of a group committee is skilfully guided on its course by a teacher without undue interference and domination of their efforts.

The rate at which ground is covered by this method at first is necessarily slow. But, as compared with an oftentimes lifeless study of textbooks, it will be found that the rate of educational advance becomes much more rapid by use of projects. Since it is a task of no small magnitude for management of projects by a teacher, it is not to be undertaken with groups too large. Sixteen is a comfortable number to handle. With a larger number supervision by a teacher lacks in definiteness of knowledge and control over what is being done by individual pupils.

Pupils when of sufficient age and dependability may be given considerable freedom when working a project. They may even be allowed to go to the public library during school hours, or visit industrial and municipal plants, in getting information relative to water supply, fire prevention, manufacture of artificial ice and illuminating gas, cold storage plants, sewage and garbage disposal, or other places to which their projects may lead. A "form letter" introducing any such pupil to some one in a plant visited to whom the instructor is personally known, stating purpose of the visit and requesting such opportunities for gaining definite information as are reasonable requests to make, will spare much grief and discouragement. The conditions named suggest within what narrow limits these projects must be confined lest the plants visited withdraw the privilege of visitations. Then, too, there must be no trespassing on the time of other teachers no matter how enthusiastic any pupil may become in his projects.

The inter-relations of things, and their mutual dependence, will manifest themselves and be impressed upon the members of a class as they take note how frequently seemingly diverse projects have much in common. At such times it is oftentimes well to let one pupil give instruction to another concerning what he himself has previously mastered. It relieves the instructor that much, and is mutually helpful to the pupils concerned. For example, where one committee working on washing soda has been assisted to an under-

standing of hydrolysis by the teacher, a pupil encountering alum in baking powder may go to a "washing-soda" pupil for help in understanding his difficulties, and both will profit by their efforts to learn and to give instructional assistance.

As a by-product of the use of projects pupils are helped in public speaking. The slowness and distinctness of speech necessary in addressing the membership of a large class in distinction from talking to the teacher comes strongly into evidence when giving reports, as does the necessity of presentations of a convincing character. After a little experience pupils can get away from reading reports to use of an outline, and in due time to presentation of a well-ordered account without any written helps. And this suggests that these "Reports," and the discussions accompanying their presentation, together with the concerted sustained effort they represent, may very suitably make these "Projects" a rich field of endeavor for the "Science Club" of the school. Where but one such club exists in school the several sciences represented in the club membership may in turn offer their contributions.

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